WATER RESOURCES REPORT 30

# WATER RESOURCES OF THE ST. LOUIS AREA, MISSOURI


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PREPARED UNDER A COOPERATIVE AGREEMENT BETWEEN

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and

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Wallace B. Howe, State Geologist and Director

Rolla, Mo., 1974

## CONTENTS

## CONTENTS *(continued)* .....



## ILLUSTRATIONS

## ILLUSTRATIONS *(continued)* . . . . .

## TABLES

**TABLES** *(continued)* . . . . .



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# WATER RESOURCES OF THE ST. LOUIS AREA, MISSOURI

## ABSTRACT

*Water supplies in the St. Louis area, Missouri, are available from streams and from bedrock and alluvial aquifers that underlie the region. Of the 1200 million gallons of water used daily, about 82 percent is pumped from the Mississippi River and about 15 percent from the Missouri and Meramec Rivers. Approximately two-thirds of this pumpage is used for cooling in the generation of electric power. The bedrock and alluvial aquifers account for 1 and 2 percent of the total pumpage, respectively.*

*The bedrock aquifers are primarily dolomite and limestone with one notable exception, the St. Peter Sandstone. Wells finished in these aquifers furnish water to 22 towns, 7 rural water-supply districts and most households not served by a central water supply. The principal bedrock aquifers are the St. Peter, the Roubidoux, the Gasconade, and the Potosi.*

*Wells yielding more than 50 gpm (gallons per minute) of potable water can be developed in bedrock aquifers in the western one-third of St. Charles County, the extreme western part of St. Louis County, and the southwestern three-fourths of Jefferson County. In these areas, wells finished in the Potosi Dolomite have yielded a maximum of 500 gpm, while others finished in the Gasconade and Roubidoux Formations have yielded a maximum of 300 gpm. Yields of 140 gpm have been reported from wells tapping the St. Peter Sandstone.*

*Only a small percentage of the water available in the alluvial aquifers of the area is being used. Areas having the greatest potential for development of ground water are in the Mississippi and Missouri River floodplains. Wells reportedly yielding as much as 3,000 gpm have been drilled in the Mississippi River floodplain in St. Charles County. A yield of over 2,500 gpm has been measured from a well in the Missouri River floodplain. In the Meramec River floodplain, municipal and industrial wells at Valley Park are capable of yielding as much as 500 gpm, while a few miles downstream the city of Kirkwood has a collector well capable of pumping 2.6 mgd (million gallons per day). Water from the alluvial deposits generally is a very hard calcium-magnesium-bicarbonate type with iron and manganese content commonly being high. Saline water has moved upward from the underlying bedrock into the alluvial aquifers at Valley Park and Times Beach in the Meramec River valley and in the Mississippi River valley near St. Peters. This upward leakage may be a naturally occurring phenomenon, but part of it probably is through boreholes of abandoned deep wells or test holes.*

*The median 7-day low flows of small unregulated tributary streams generally range from 0 to 0.005 cfs (cubic feet per second) per square mile in the northern two-thirds of the area and from 0.02 to 0.05 cfs per square mile elsewhere. These values can be as high as 0.3 cfs per square mile in urban areas because of augmentation from sewage treatment plants. Because the natural low flow of many of these tributary streams is less than 0.5 cfs, an influx of poor-quality effluent, even though in small amounts, will be enough to seriously degrade the water quality in the stream.*

*Except for larger streams such as the Meramec, Big, and Cuivre Rivers, storage facilities would be required to develop dependable surface-water supplies*

*in the tributary basins. The principal factors limiting future development will be a lack of natural sustained low flows and the quality of the water, which is often very poor in urbanized areas and requires extensive treatment prior to use.*

*Flooding can occur in the area during all months, but is most common in the March-through-July period. Many of the larger floods on record were caused by intense, local summer thunderstorms. Analysis of data from an urbanized basin in the area indicates that peak flows are increased at least one-and-a-half to two times by significant urbanization.*

*Quality of surface water varies from good in the tributary streams of southern Jefferson County to very poor in the highly urbanized areas. The major sources of surface-water supplies are the Missouri, Mississippi and Meramec Rivers. Except for water used for once-through cooling, extensive treatment of water from these streams is required prior to use for domestic and most manufacturing purposes.*

# INTRODUCTION

## PURPOSE AND SCOPE

A consistent pattern of rapid growth during the past two decades has increasingly concentrated people and activities around metropolitan areas such as St. Louis. This concentration has caused a multitude of problems with some of the most pressing being in the field of water resources, where coordinated planning is essential to optimum mangement.

The purpose of this report is to summarize and interpret hydrologic data presently available for St. Louis, St. Charles and Jefferson Counties; to evaluate the water resources of the area; and to relate water needs to available supplies.

A generalized description of the hydrologic effects of urbanization in the area is also presented. Data now being collected on small urban and rural streams in St. Louis County will eventually provide more precise design data for use by urban planners and water managers.

## COOPERATION AND ACKNOWLEDGMENTS

This report is the result of a cooperative study conducted by the Missouri Geological Survey and Water Resources (Dr. William C. Hayes, State Geologist and Director, succeeded by Dr. Wallace B. Howe) and the U.S. Geological Survey (Anthony Homyk, District Chief, Missouri District).

Appreciation is expressed to the Missouri Clean Water Commission (formerly the Missouri Water Pollution Board), the City of St. Louis (Water Division), and the St. Louis County Water Company for their assistance in the collection of water-quality information.

Thanks are also due the State Highway Department, drilling contractors, and many homeowners who furnished information and helped in collecting supporting data.

The authors drew heavily on hydrogeologic data collected over a period of many years by the Missouri Geological Survey and Water Resources. Of particular value were the extensive well-log files accumulated by the Missouri Geological Survey through the cooperation of many well-drilling contractors throughout the state and data obtained through a continuing cooperative stream-gaging program between the Missouri Geological Survey and the U.S. Geological Survey.

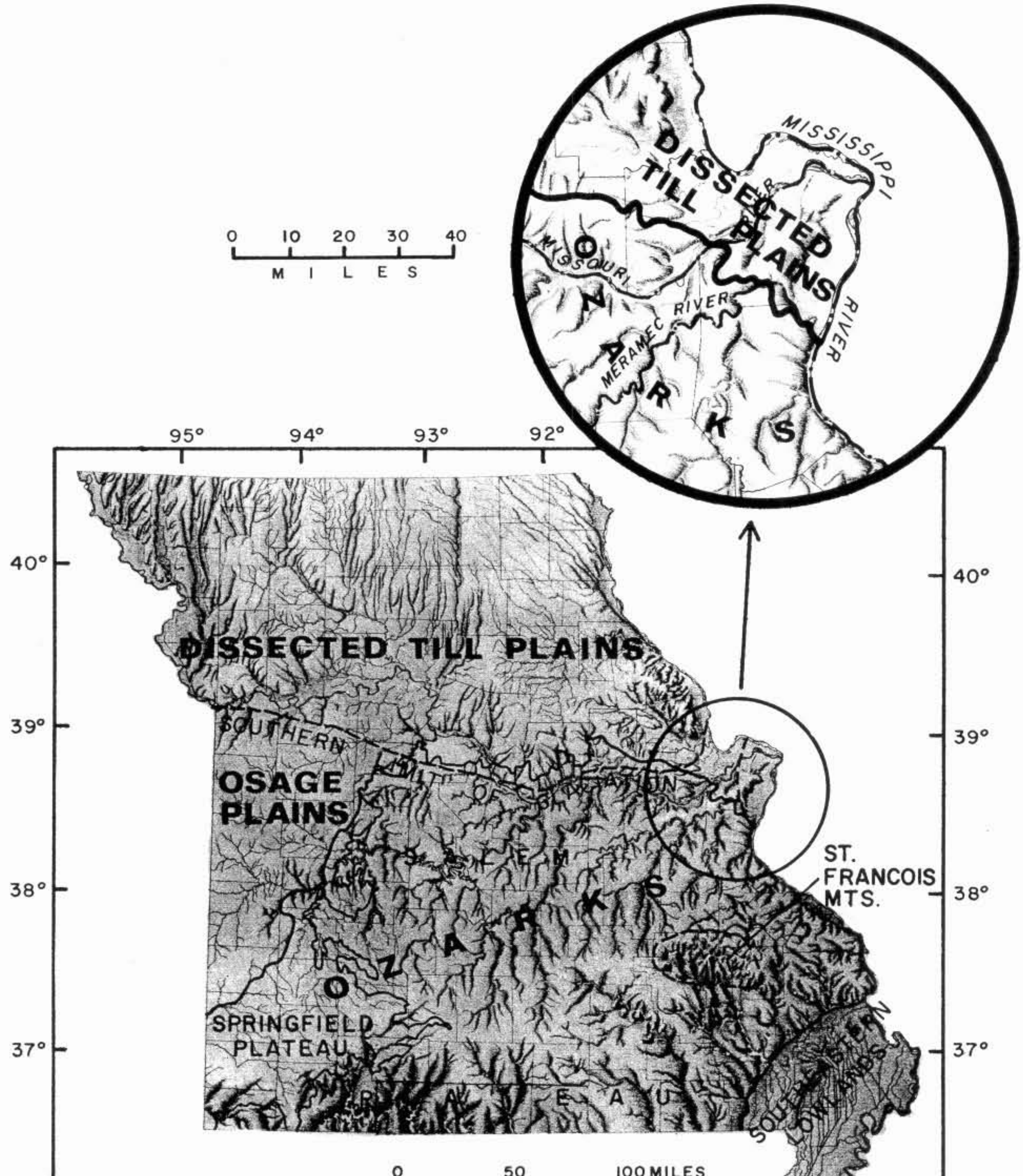



Figure 1

*Location and physiography of study area.*

## GEOGRAPHY

The study area (fig. 1) is in a part of eastern Missouri which includes the confluence of two of the nation's largest rivers — the Missouri and the Mississippi. A diversity of land forms and drainage features are included in the area encompassed by St. Louis, St. Charles and Jefferson Counties.

The area lies within two physiographic provinces. The northeastern two-thirds of St. Charles and St. Louis Counties and the extreme northeastern part of Jefferson County, adjacent to the Meramec River, lie within the Dissected Till Plains. The remainder of the area lies within the Salem Plateau of the Ozarks (Fenneman, 1946).

The Dissected Till Plains is gently undulating, with altitudes ranging from 500 to 700 feet. The morainal topography seen over much of the adjacent glaciated areas is noticeably lacking here. This particular area was glaciated twice during the Pleistocene, but the till deposits are thin and dissected.

The topography developed in the Ozarks province of the study area is submature to mature. The uplands may be broad flats, but are generally thoroughly dissected while most of the divides are narrow and irregular. Topographic slopes are locally reflections of the regional dip of from 60 to 80 feet per mile to the northeast. Variations in hardness of the Paleozoic rocks are shown by escarpments on the more resistant formations. These escarpments face southwestward, more or less parallel to the Ozark uplift (Marbut, 1896). Altitudes in the Ozarks range from 650 to 1,000 feet, except in the stream valleys where altitudes are from 400 to 650 feet.

All runoff from the land surface in the area eventually reaches the Mississippi or Missouri Rivers through a network of tributary streams that form a dendritic drainage pattern (fig. 2). The floodplains of each of these two great rivers are as much as 11 miles wide in some places and are bordered by loess-covered uplands.

Practically all of the area is shown on modern 7½-minute topographic maps (fig. 3). The balance has 15-minute topographic map coverage.

## WELL LOCATION SYSTEM

Wells used in this report are located in accordance with the Bureau of Land Management Survey system, in this order: township, range, section, quarter section, quarter-quarter section and quarter-quarter-quarter section (10-acre tract). The subdivisions of a section are designated a, b, c, and d in counterclockwise direction beginning in the northeast quarter. If several wells are in a 10-acre tract, they are numbered serially after the above letters, and in the order in which they were inventoried (fig. 4).

## GEOLOGY

It is beyond the scope of this report to describe in detail the stratigraphic and structural setting of the study area. It will be necessary, however, to acquaint the reader with the rock units and their structural attitudes so that references to these rocks as aquifers can be understood. Numerous published and unpublished stratigraphic studies have been made in this area and the reader is referred to these (Stout, 1969, p. 50-57) for more detailed geologic information.

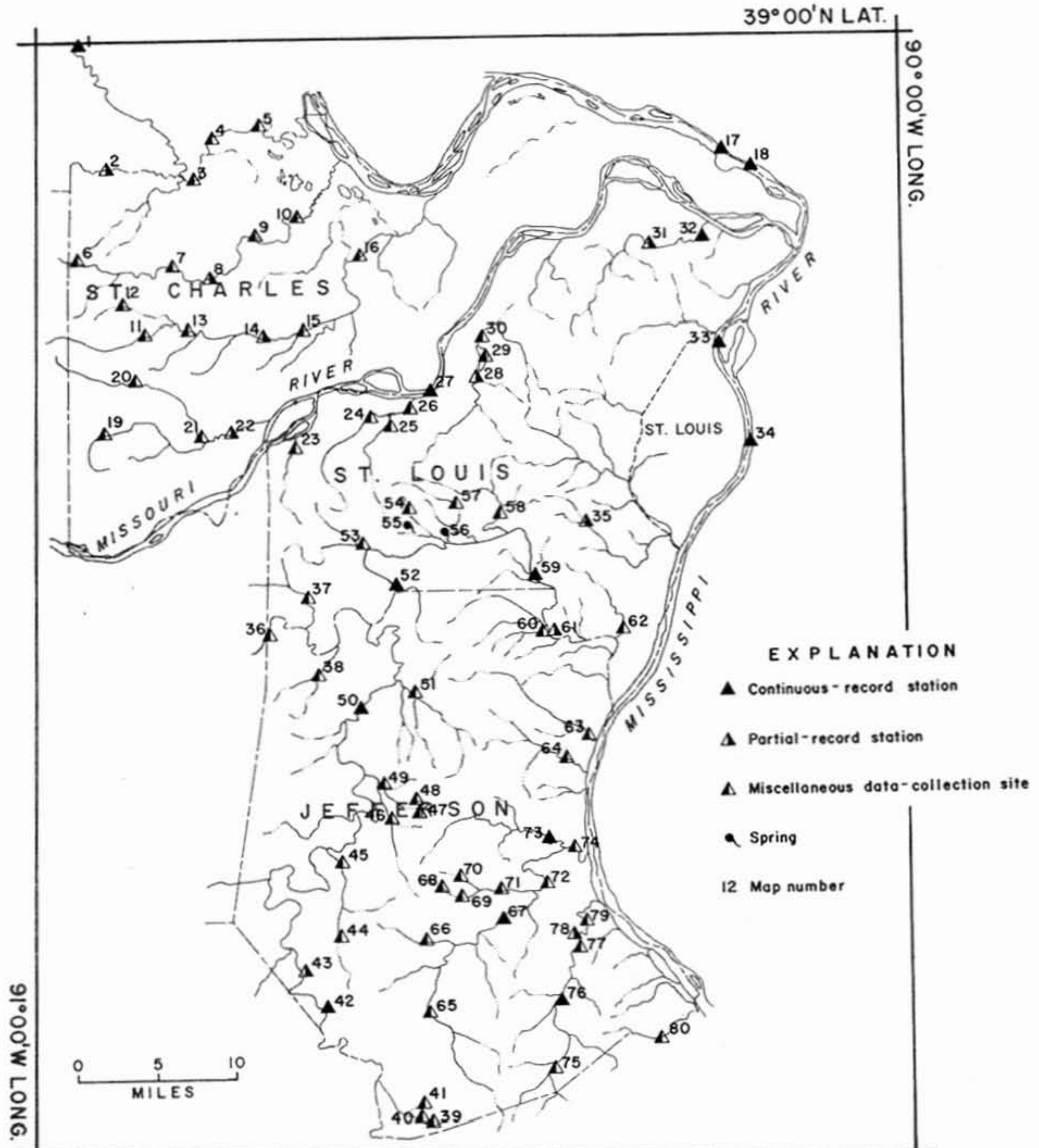



Figure 2

*Streamflow data-collection sites in the St. Louis area, Missouri.*

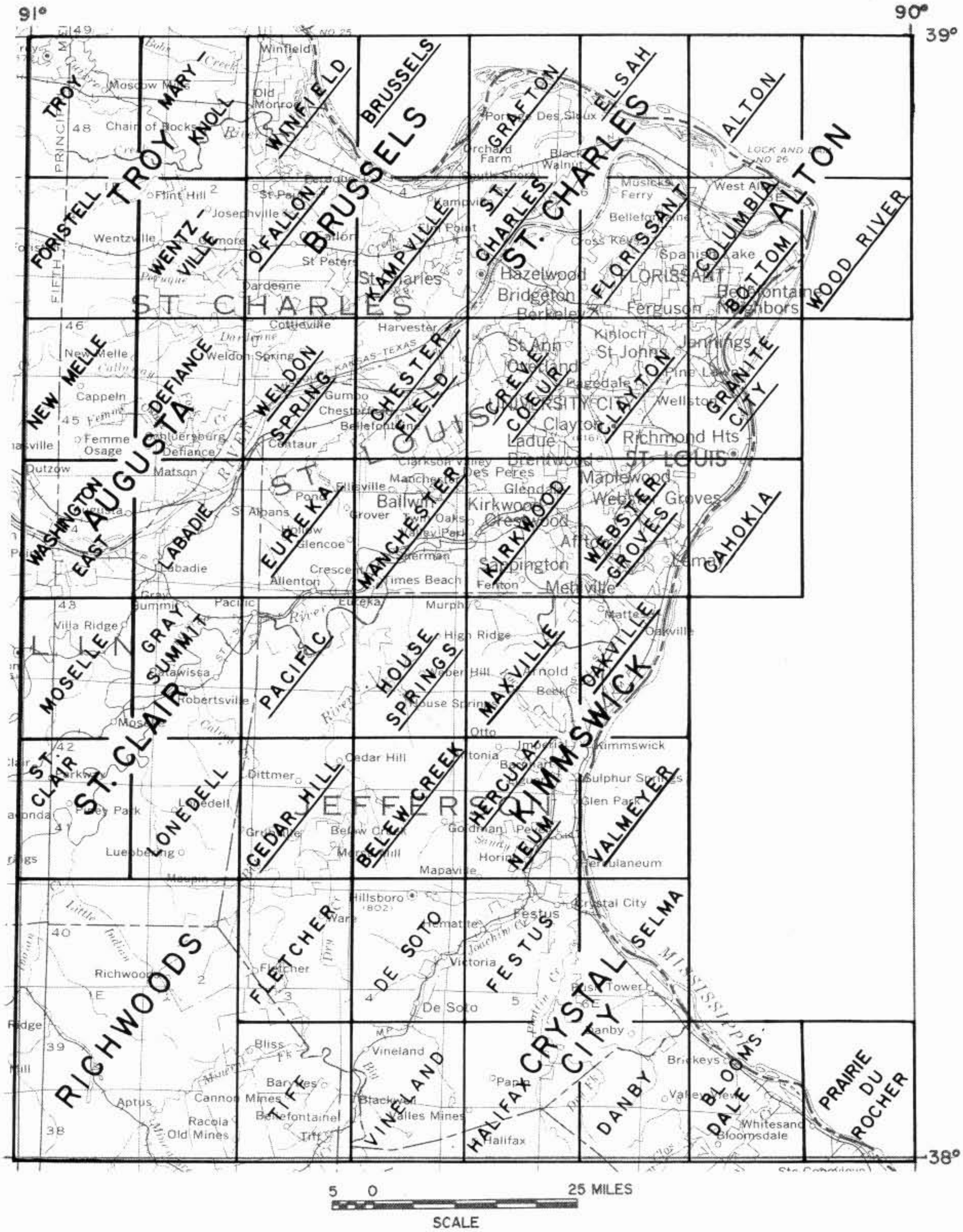



Figure 3

*Topographic map coverage of the St. Louis area. (Underlining of quadrangle name indicates interim revision 1968).*

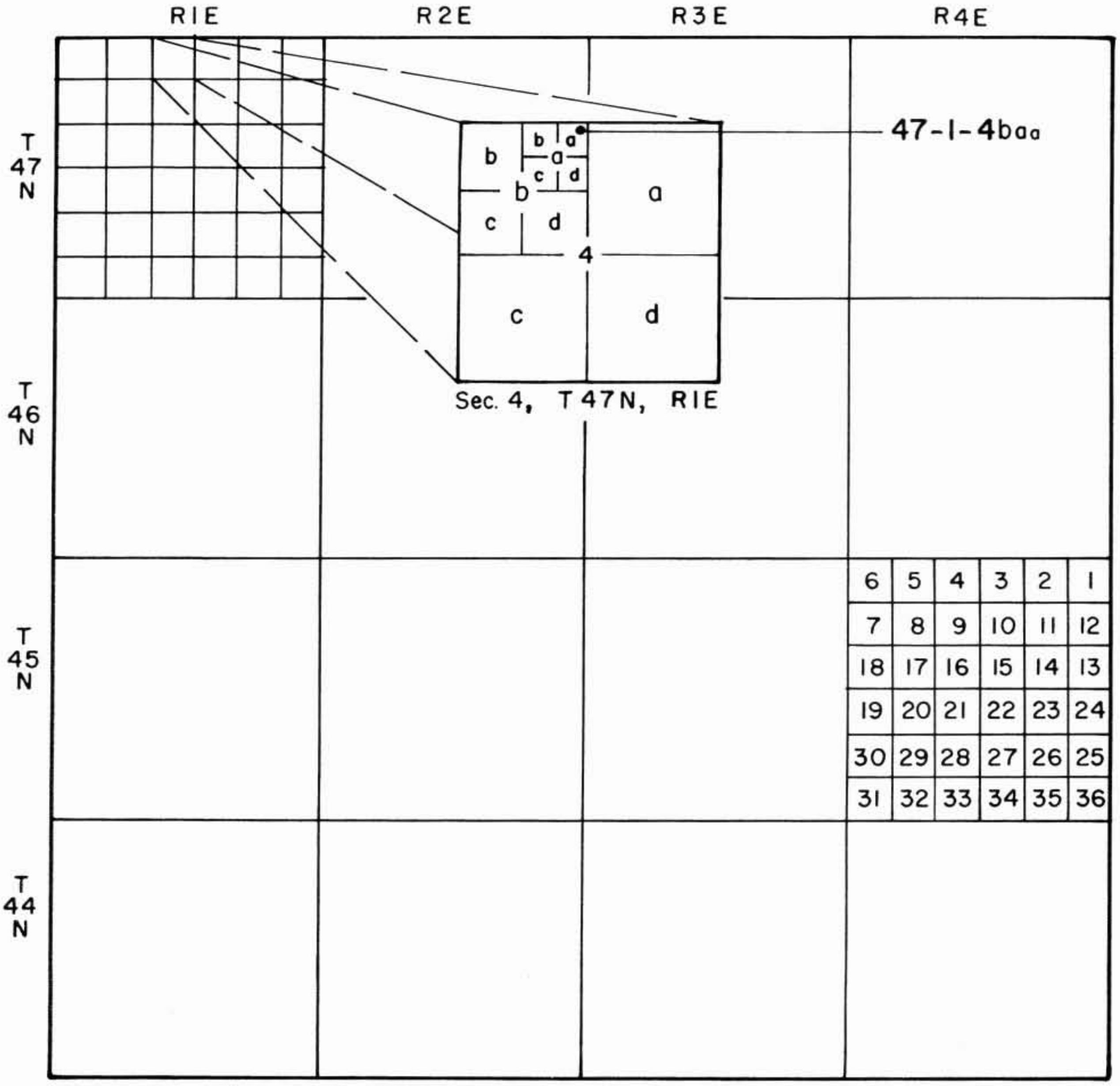



Figure 4

*The well location system used in this report is a shortened version of that normally used to describe a location. Subdivisions of the section are shown by letters.*

## Table 1

## Generalized stratigraphic column for St. Louis, St. Charles, and Jefferson Counties, Missouri

Aquifers most favorable as water sources are shaded

| System | Series | Group | Formation | Aquifer group | Thickness (feet) | Dominant lithology | Water-bearing character |
|---|---|---|---|---|---|---|---|
| | Holocene | | Alluvium1/ | | 0-150 | Sand, gravel, silt, and clay. | Some wells yield more than 2,000 gpm. |
| Quaternary | Pleistocene | | Loess | | 0-110 | Silt | |
| | | | Glacial till | | 0-55 | Pebbly clay and silt. | Essentially not water yielding |
| | Missourian | Pleasanton | Undifferentiated | | 0-75 | Shales, siltstones, "dirty" sandstones, coal beds and thin limestone beds. | Generally yields very small quantities of water to wells. Yields range from 0-10 gpm. |
| | | Marmaton | Undifferentiated | | 0-90 | | |
| Pennsylvanian | Desmoinesian | Cherokee | Undifferentiated | | 0-200 | | |
| | Atokan | | Undifferentiated | | | | |
| | | | Ste. Genevieve Formation | | 0-160 | | |
| | Meramecian | | St. Louis Limestone | | 0-180 | Argillaceous to arenaceous limestone. | |
| | | | Salem Formation | | 0-180 | | |
| | | | Warsaw Formation | | 0-110 | | |
| | | | Burlington-Keokuk Limestone | 1 | 0-240 | Cherty limestone | |
| Mississippian | Osagean | | Fern Glen Formation | | 0-105 | Red limestone and shale. | Yields small to moderate quantities of water to wells. Yields range from 5 to 50 gpm. Higher yields are reported for this interval locally. |
| | Kinderhookian | Chouteau | Undifferentiated | | 0-122 | Limestone, dolomitic limestone, shale, and siltstone. | |
| | Upper | Sulphur Springs | Bushberg Sandstone | | 0-60 | Limestone and sandstone. | |
| Devonian | | | Glen Park Limestone | | | | |
| | | | Grassy Creek Shale | | 0-50 | Fissile, carbonaceous shale. | |
| Silurian | | | Undifferentiated | | 0-200 | Cherty limestone. | |
| | | | Maquoketa Shale | | 0-163 | Silty, calcareous or dolomitic shale. | Probably constitutes a confining influence on water movement. |
| | Cincinnatian | | Cape Limestone | | 0-5 | Argillaceous limestone. | |
| | | | Kimmswick Formation | | 0-145 | Massive limestone | |
| | | | Decorah Formation | | 0-50 | Shale with interbedded limestone. | Yields small to moderate quantities of water to wells. Yields range from 3 to 50 gpm. Decorah Formation probably acts as a confining bed locally. |
| | Champlainian | | Plattin Formation | 2 | 0-240 | Finely crystalline limestone. | |
| | | | Rock Levee Formation | | 0-93 | Dolomite and limestone, some shale. | |
| | | | Joachim Dolomite | | 0-135 | Primarily argillaceous dolomite. | |
| Ordovician | | | St. Peter Sandstone | | 0-160 | | |
| | | | Everton Formation | 3 | 0-130 | Silty sandstone, cherty limestone grading upward into quartzose sandstone. | Yields moderate quantities of water to wells. Yields range from 10-140 gpm. |
| | | | Powell Dolomite | | 0-150 | | |
| | Canadian | | Cotter Dolomite | | 0-320 | Sandy and cherty dolomites and sandstone. | Yields small to large quantities of water to wells. Yields range from 10 to 300 gpm. Upper part of aquifer group yields only small amounts of water to wells. |
| | | | Jefferson City Dolomite | 4 | 0-225 | | |
| | | | Roubidoux Formation | | 0-177 | | |
| | | | Gasconade Dolomite Gunter Sandstone Member | | 0-280 | | |
| | | | Eminence Dolomite | | 0-172 | | Yields moderate to large quantities of water to wells. Yields range from 10 to 400 gpm. |
| | | | Potosi Dolomite | | 0-325 | Cherty dolomites, siltstones, sandstone, and shale. | |
| Cambrian | Upper | Elvins | Derby-Doerun Dolomite | 5 | 0-165 | | |
| | | | Davis Formation | | 0-150 | | |
| | | | Bonneterre Formation | | 245-385 | | |
| | | | Lamotte Sandstone | | 235+ | | |
| Precambrian | | | | | | Igneous and metamorphic rocks. | Does not yield water to wells in this area. |

1/ Basal part may be of Pleistocene age.

NOTE: Stratigraphic nomenclature may not necessarily be that of the U.S. Geological Survey.

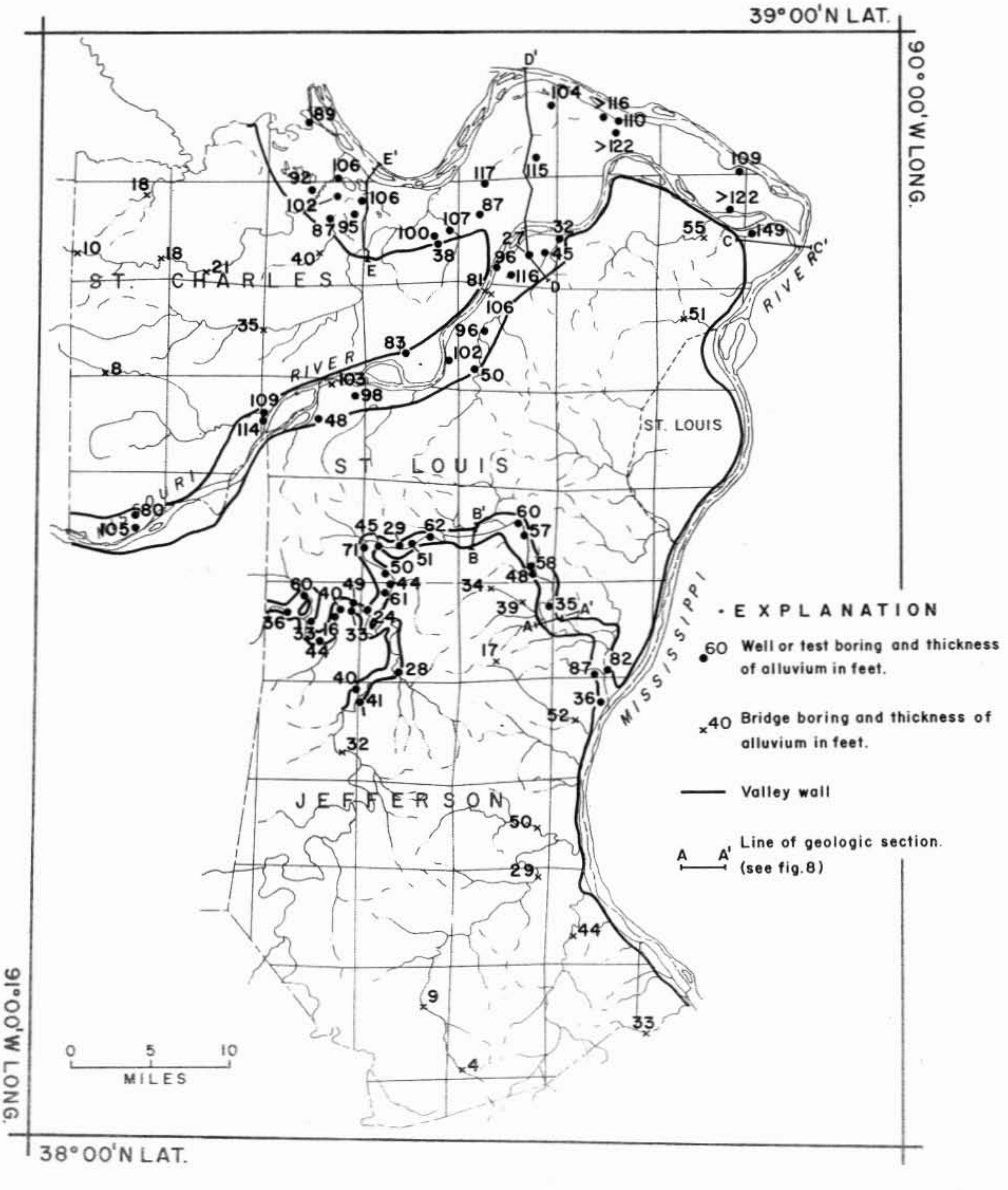



Figure 5

*Thickness of alluvium along the Mississippi, Missouri, Meramec and lower Big Rivers, and some tributary streams.*

## STRATIGRAPHY

The stratigraphic sequence consists primarily of limestone and dolomite which were deposited, for the most part, in shallow epicontinental seas. Rocks range in age from Precambrian to Holocene. A composite stratigraphic section showing these rocks and their water-bearing properties is given in table 1. The Precambrian rocks, the Lamotte Sandstone, and the lower part of the Bonneterre Formation are the only units that do not crop out in the area; they are, however, present in the subsurface. Many periods of emergence, nondeposition or erosion are implied by the disconformities and local unconformities observed in surface exposures and well data. These breaks in the stratigraphic record are shown in table 1 by wavy lines.

Many of the stratigraphic units are not present locally; consequently, no wells penetrated all the formations shown in table 1. Formations penetrated while drilling a well depend on the geographic location. For example, wells drilled in southern Jefferson County start lower in the stratigraphic section and hence do not penetrate many of the formations shown in table 1.

The only deposits of Cenozoic age having significant water-yielding properties are the water-saturated sands and gravels in the alluvium. It is possible that the basal portion of part of the fill in the large valleys is actually of Pleistocene age (Bergstrom and Walker, 1956, p. 31). However, since no attempt has been made to differentiate the valley fill as to age in this report, it is referred to as alluvium.

Alluvium underlying the floodplains and terraces of the Mississippi, Missouri and Meramec Rivers extends over 277 square miles in the three-county area. The thickness of the alluvium is variable because of irregularities in the bedrock surface upon which it was deposited. The maximum known thickness of alluvium (150 feet) was penetrated by a test hole drilled in the Columbia Bottoms near the mouth of the Missouri River. The areal extent and the thickness of the alluvium at selected points is shown in figure 5. The alluvium is composed of clay, silt, sand and gravel. In general, the alluvium becomes coarser-grained with depth. It is this deeply buried, coarser-grained material which, when well-sorted and water-saturated, comprises the most water-productive part of the alluvial aquifer.

## STRUCTURE

The present structural attitude of the rock units is the result of compressional, tensional and uplifting forces which moved and altered the units from their original depositional positions. These forces have folded, fractured, faulted, and tilted the rocks in the study area, and the resulting structures are superimposed on a regional dip or large-scale tilting of the rock units of from 60 to 80 feet per mile to the northeast. Figure 6 shows some of the major structures in the St. Louis area.

The reader is referred to McCracken (1966) and Trapp (1961, unpublished data) for a more complete description of the structures in the St. Louis area.

# SOURCES OF WATER

St. Louis, near the confluence of the Missouri and Mississippi Rivers, is well situated with respect to surface-water supplies. In addition, the area has the benefit of the Meramec River, which carries a large flow of good-quality water to the Mississippi just south of St. Louis. These rivers furnish nearly all of

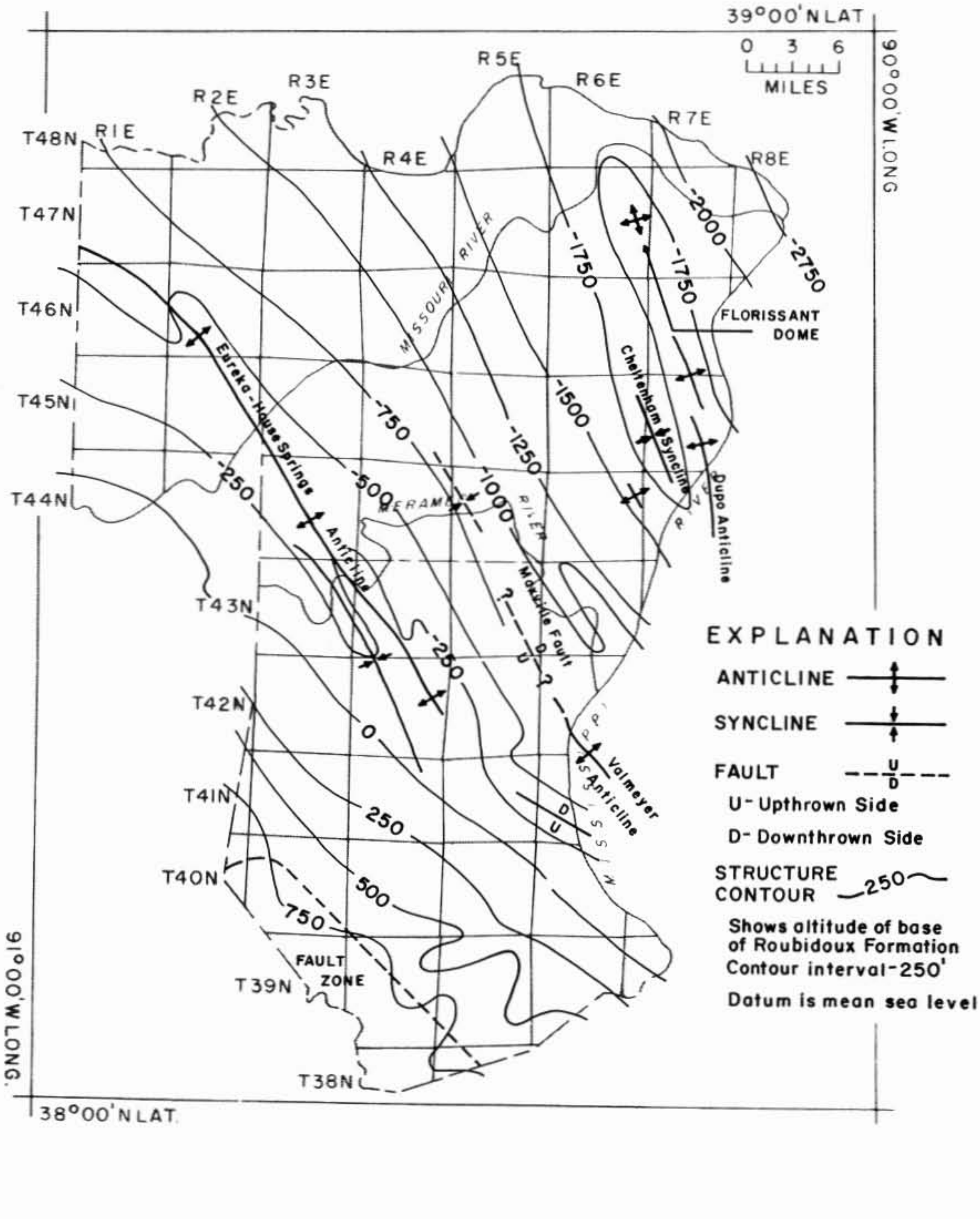



Figure 6

*Major structural features of the St. Louis area and structural contours on the base of the Roubidoux Formation (based on McCracken and McCracken, 1965).*

the water used in the three counties while their tributary streams are used for recreation or waste transportation. In addition to surface-water sources, a large amount of water is available to the area from the underlying rocks. Though some ground water is too mineralized to use, much is fresh and of good quality. Little of the ground water in storage is used.

## GROUND WATER

Large amounts of fresh water are stored in the bedrock and alluvium underlying the area. Water occurs in the bedrock along fractures and bedding planes as well as in solution openings in the limestone and dolomite, and in voids between the grains in sandstone. Shale is generally impervious to the movement of water and is usually not a source of supply. The availability of water from bedrock depends upon the amount of fracturing and solution which the rocks have undergone and the degree to which these openings are interconnected. Water in the alluvium occurs in the openings between the individual sand and gravel particles of which the aquifer is composed. The availability of water from the alluvium depends upon the degree of sorting of the material, its saturated thickness, its hydraulic connection with a surface-water source, and infiltration of rainfall.

Locations of wells and test holes used for compiling hydrogeologic data for this report are shown on plate 1.

### AQUIFERS

Most wells drilled into bedrock in the study area are left open below a certain casing depth. This casing depth is determined by the presence and degree of weathering, and by connections with surface-water sources. Individually, many of the rock units shown on table 1 yield only small amounts of water. Collectively, however, these units may yield sufficient water to supply the needs of most water users. For this reason, it was considered practical to treat large sequences of both water-bearing and non-water-bearing rocks as one large aquifer or aquifer group. The bedrock units are thus assigned to five groups based on similar lithologic characteristics, geographic distribution, and overall similarity of water quality. Also of prime importance are the presence of confining beds at aquifer group boundaries and the presence of thick sequences of rock which, although not to be considered confining, yield very little water to wells (see table 1).

Group 1 (Post-Maquoketa) includes all bedrock units above the Maquoketa Shale, which probably acts as a confining bed in the study area. Pennsylvanian rocks at the upper boundary of Group 1 are relatively impermeable and yield very little water to wells. Group 2 (Kimmswick-Joachim) includes all aquifers between the base of the Maquoketa Formation and the base of the Joachim Formation. The Joachim is not considered to be a good aquifer in other parts of the state and, although it is not a confining bed, it probably does not yield water in quantities large enough for it to be considered an aquifer.

Group 3 (St. Peter-Everton) includes the St. Peter Sandstone and the Everton Formation. Group 4 (Powell-Gasconade) includes all units in the Canadian Series of Early Ordovician age. The lower part of the Everton Formation and the upper three units of the Canadian (Powell, Cotter, and Jefferson City Dolomites) are not prolific water-bearing units. Small supplies can be developed in these units, but they are subject to failure during extended periods of drought or sustained pumping.

Group 5 (Eminence-Lamotte) includes all units below the base of the Gasconade Dolomite. The Eminence Dolomite is similar to the upper three units of the Canadian Series in its water-bearing characteristics and hence constitutes a good boundary marker between more prolific aquifers. Figure 7 is a geologic map showing the distribution of the aquifer groups discussed above.

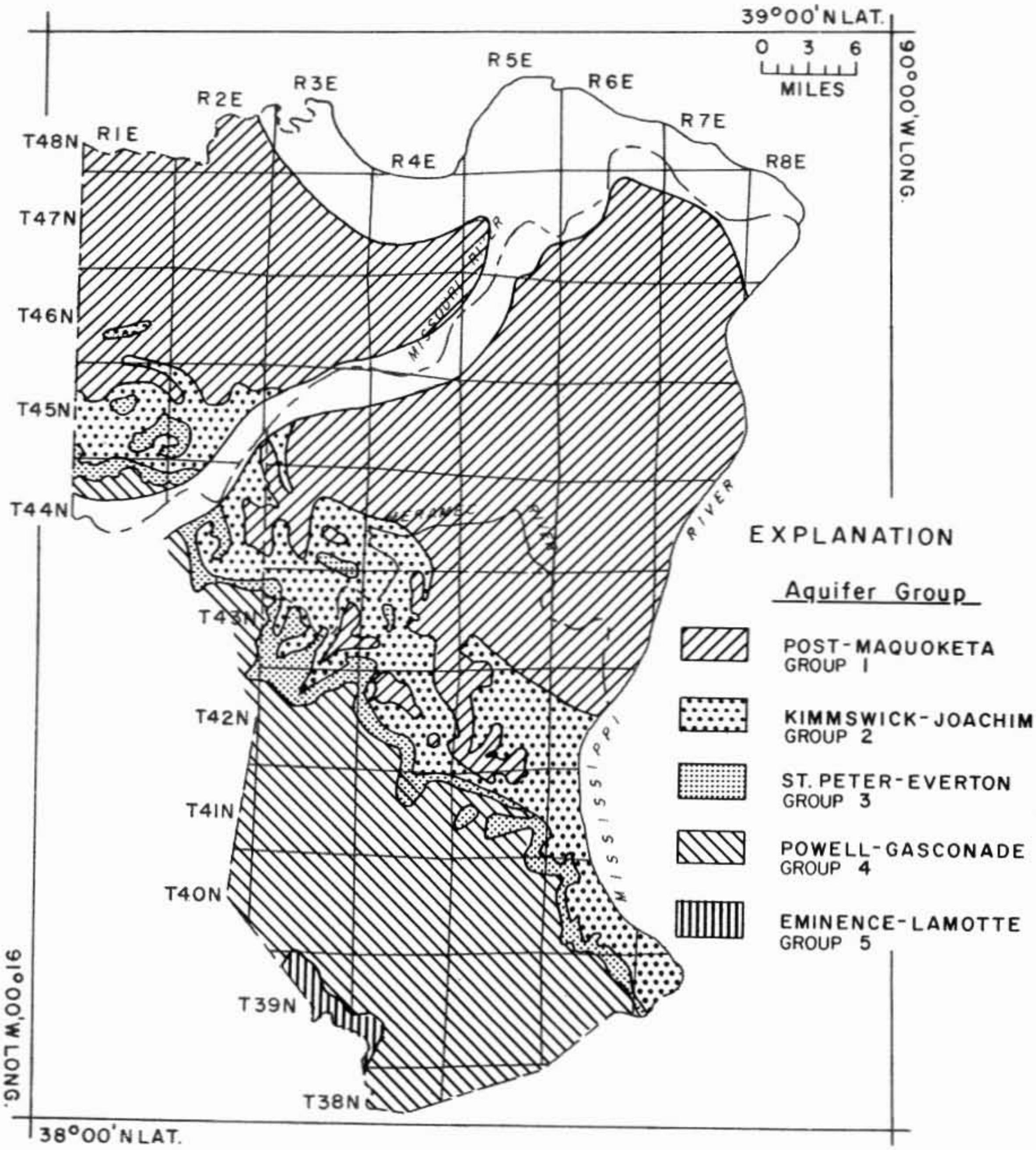



Figure 7

*Geologic map showing distribution of aquifer groups. Numerals indicate aquifer groups. (See table 1 for more detail.)*

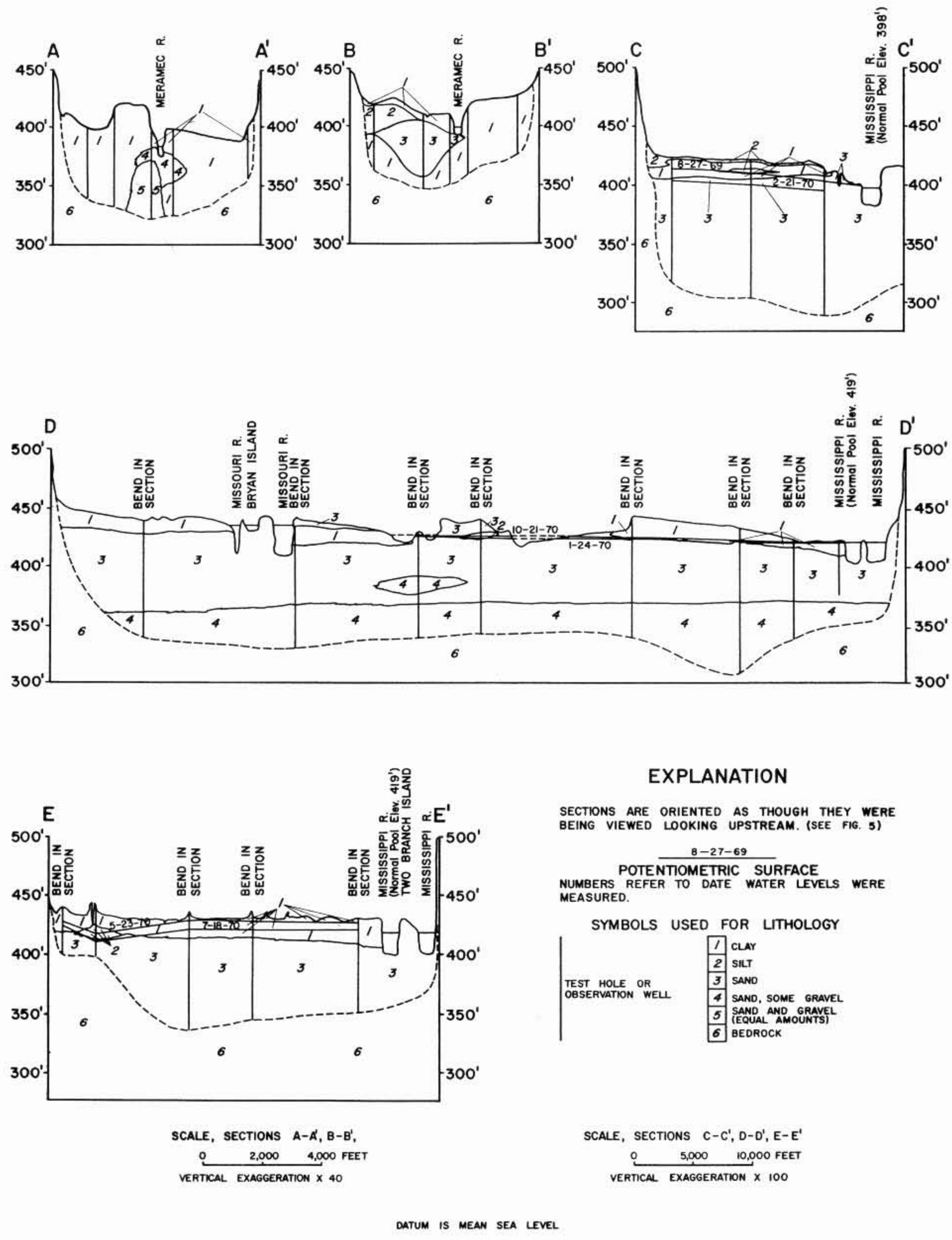



Figure 8

*Hydrogeologic sections.*

Major alluvial aquifers in the area are the water-saturated sands and gravels in the basal part of the alluvium underlying the floodplains of the Mississippi, Missouri and Meramec Rivers. Water-bearing sands and gravels also underlie the floodplains of the Big River and other perennial streams of the area. Records of well yields from these relatively thin alluvial deposits are not available, but it is believed that yields would generally be small to conventional vertical wells because of less saturated thickness.

The alluvial deposits are composed of varying proportions of clay, silt, sand, and gravel. The value of the alluvium as a source of water depends on its thickness and the size and sorting of the materials. The greater the proportion of clay, silt and fine sand, the poorer the aquifer would be. Conversely, well-sorted, clean sands and gravels would yield large quantities of water.

Because of the scour-and-fill method of deposition, alluvial deposits may vary considerably in sorting and texture within a small area. This is readily apparent in a comparison of geologic sections (fig. 8) of the Mississippi and Missouri Rivers with sections of the Meramec River. This variability points up the need for adequate test drilling prior to any large-scale development of ground water from the alluvium.

Geologic logs of some of the more favorable sites for potential groundwater development in the alluvial areas are included in Appendix 1, and their locations are shown on plate 1. Geologic logs of many of the wells shown on plate 1 are available in the files of the Missouri Geological Survey and Water Resources.

## GROUNDWATER RECHARGE

The bedrock aquifers receive recharge from precipitation falling directly on the area. The amount of recharge from precipitation depends upon the general configuration and physical character of the land surface, the amount and type of vegetation, the distribution and quantity of precipitation, and the composition and moisture content of the soil and underlying rock. Movement of water from the soil and subsoil into the bedrock takes place along fractures and solution openings in the rock.

In areas where bedrock is exposed at the surface, conditions are not as favorable for recharge as in areas where the bedrock is not exposed. Recharge to the groundwater reservoir in the bedrock outcrop area is minimal and almost all of the precipitation leaves the area directly as runoff. Shallow bedrock aquifers that are hydraulically connected with the rivers also receive recharge from natural infiltration of the rivers during sustained high-river stage and flooding.

Alluvial aquifers in the area are recharged by infiltration of stream water during sustained high-river stage and flooding, by direct precipitation, and by underflow from underlying and adjacent bedrock.

Recharge from precipitation to the hydrogeologically-similar East St. Louis alluvial area, adjacent to the study area, has been estimated to be 65 mgd (million gallons per day) for 175 square miles (Schicht, 1965, p. 46). Schicht also estimated the average rate of subsurface flow of water from the valley wall to be 329,000 gpd/mi (gallons per day per mile). If the MIssissippi, Missouri and Meramec River alluvium in the study area were to receive recharge from precipitation at a rate comparable to that estimated for the East St. Louis area, it would amount to approximately 100 mgd. However, because pumpage from the alluvium is not sufficient to lower water levels and make more storage area available, not all of the potential recharge enters the aquifer.

The sum of these sources, recharge from precipitation and underflow from the underlying and adjacent bedrock, theoretically is the amount of water that can be pumped from the alluvial aquifers without causing an overdraft or recharge from the rivers. This information is presented only to show the magnitude of the potential yield from alluvial aquifers by natural recharge alone.

An alluvial aquifer may also receive recharge from the river when large-capacity wells lower the water level in the aquifer so that the natural groundwater flow toward the stream is reversed. This causes water to move from the stream through the aquifer to the wells. Such induced recharge occurs in the Meramec River alluvium at Times Beach and in the Valley Park-Kirkwood area. Induced recharge undoubtedly occurred in the Missouri River alluvium

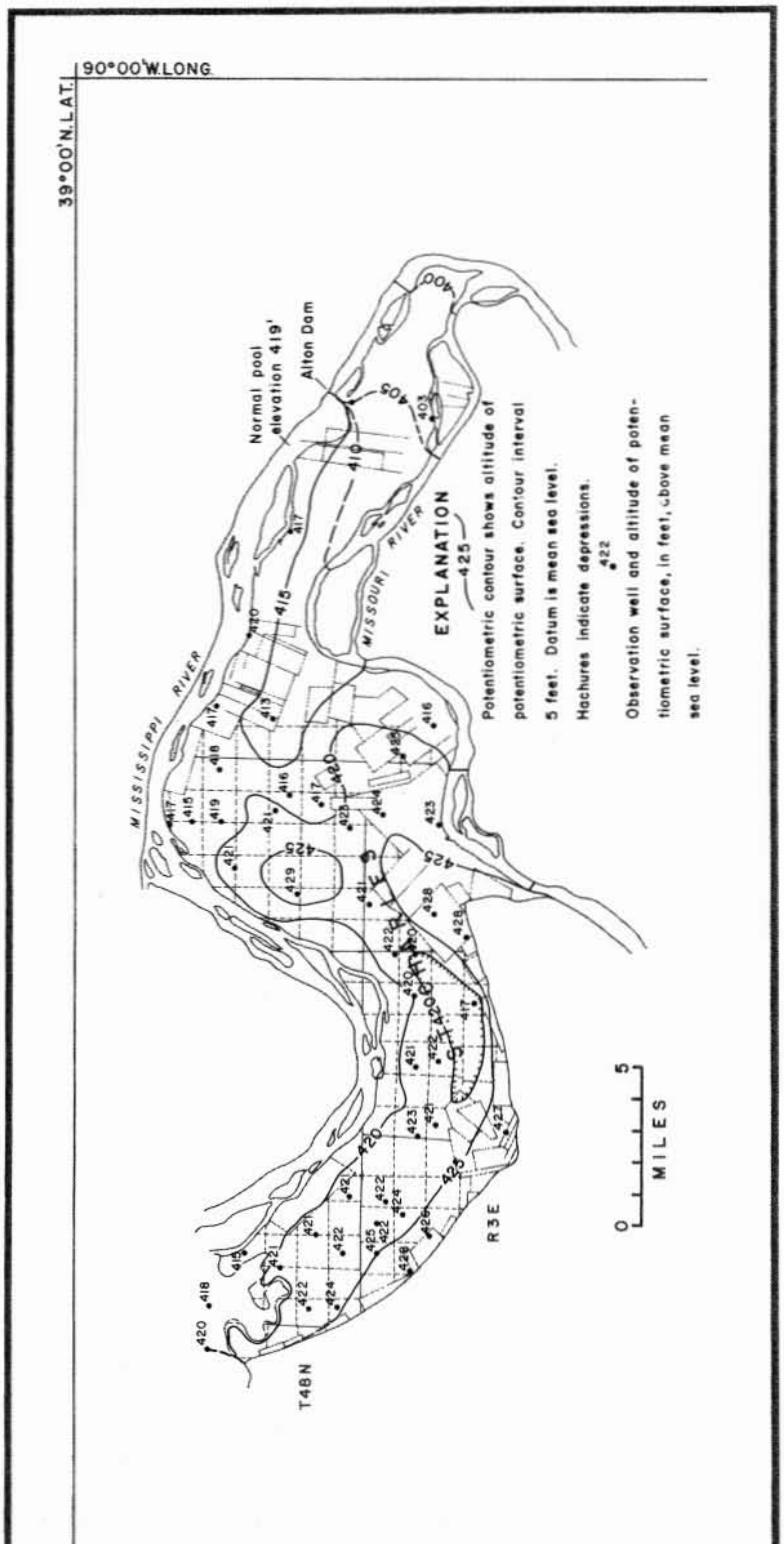



Figure 9

*Potentiometric surface of the alluvial aquifer, Alton Lake Bottoms, St. Charles County, Mo., September 1970.*

when the well field of the Weldon Springs Ordnance Plant was in operation (Emmett and Jeffery, 1968). Areas of induced recharge occur in the Mississippi River alluvium in Illinois (Schicht, 1965, p. 47) and in at least one location (Crystal City) in Missouri. Undoubtedly there are many other areas in the Mississippi River alluvium in Missouri where induced recharge could take place. If extensive development of the alluvial aquifers were to take place in the study area, sustained pumping would depend upon induced recharge from the rivers.

Data were not available to determine induced infiltration rates of streams in the study area. However, Schicht (1965, p. 1), from analysis of aquifer tests in the East St. Louis, Ill. area, found that the infiltration rate of the Mississippi River bed ranged from 37,500 to 344,000 gpd/acre/ft (gallons per day per acre per foot).

## GROUNDWATER MOVEMENT

The direction of groundwater movement can be determined for any specific time from the configuration of the groundwater surface on a potentiometric map. Such a map is shown in figure 9. Ground water moves in a direction that is down gradient and at right angles to contours on the potentiometric surface.

Wells drilled into the bedrock aquifers in the study area encounter confined, or artesian, ground water. The hydrostatic pressure, or "head", in these aquifers raises the water level in the well above the point where it was first encountered in drilling. Any movement of ground water is from areas of higher hydrostatic pressure to areas of lower hydrostatic pressure.

Potentiometric maps of bedrock aquifers could only be constructed in geographically restricted areas because of the manner in which bedrock wells in the study area are constructed. In most instances wells penetrate more than one aquifer group and each aquifer group has a separate and distinct potentiometric surface. It is probable, however, that some hydraulic connection exists between aquifer groups in the study area. Movement of ground water between aquifers due to head differences in the units occurs in areas where sufficient permeability exists at contacts between units.

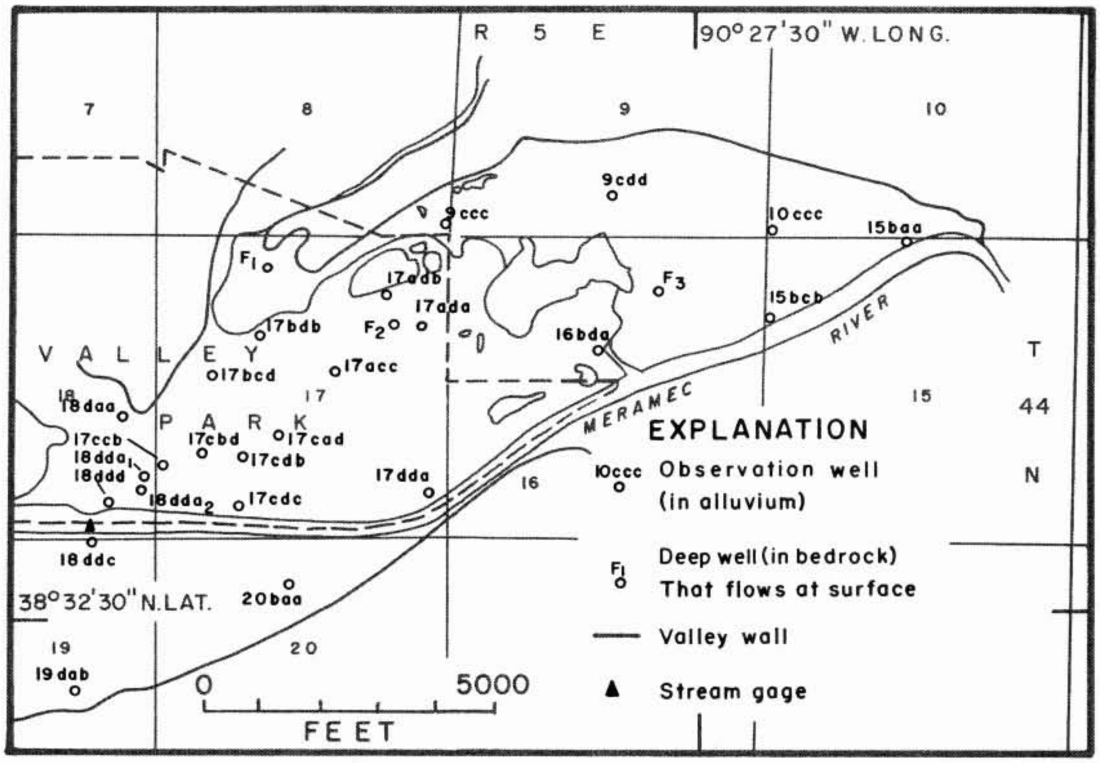
Movement of ground water in the alluvial aquifers is generally toward the major streams with which they are hydraulically connected (fig. 9), except where the movement is reversed during floods or sustained high-river stages, or by high-capacity wells pumping close enough to the river to induce recharge. An example of wells causing induced recharge is found in the Valley Park-Kirkwood area (fig. 10).

The groundwater surface in the alluvial aquifer fluctuates in response to changes in the river stage and to variations in precipitation and pumpage from wells. Figure 8 shows maximum and minimum water levels measured in selected parts of the alluvial aquifers during this investigation.

## GROUNDWATER DISCHARGE

Water recharged to the groundwater body moves down gradient in the direction of the slope of the potentiometric surface until it moves out of the study area or is discharged by natural or artificial means. Discharge is accomplished by evaporation, plant transpiration, discharge by springs, seepage into streams, or by pumpage from wells. Over long periods of time, discharge is balanced by recharge, and water levels are not drastically affected.

An undetermined amount of discharge from deeper aquifers into shallower aquifers is taking place in the study area. In areas such as Valley Park, where deep wells have been improperly cased or where casings have deteriorated, mineralized water from deeper aquifers has moved up into shallower horizons and, where head differences permit, some water is undoubtedly moving from shallow aquifers into deeper ones through wells.




EXPLANATION
(for b & c)

389
o
Observation well and altitude of potentiometric surface, in feet, above mean sea level.

F1
o
Deep well (in bedrock) that flows at surface.

oP
Pumping well

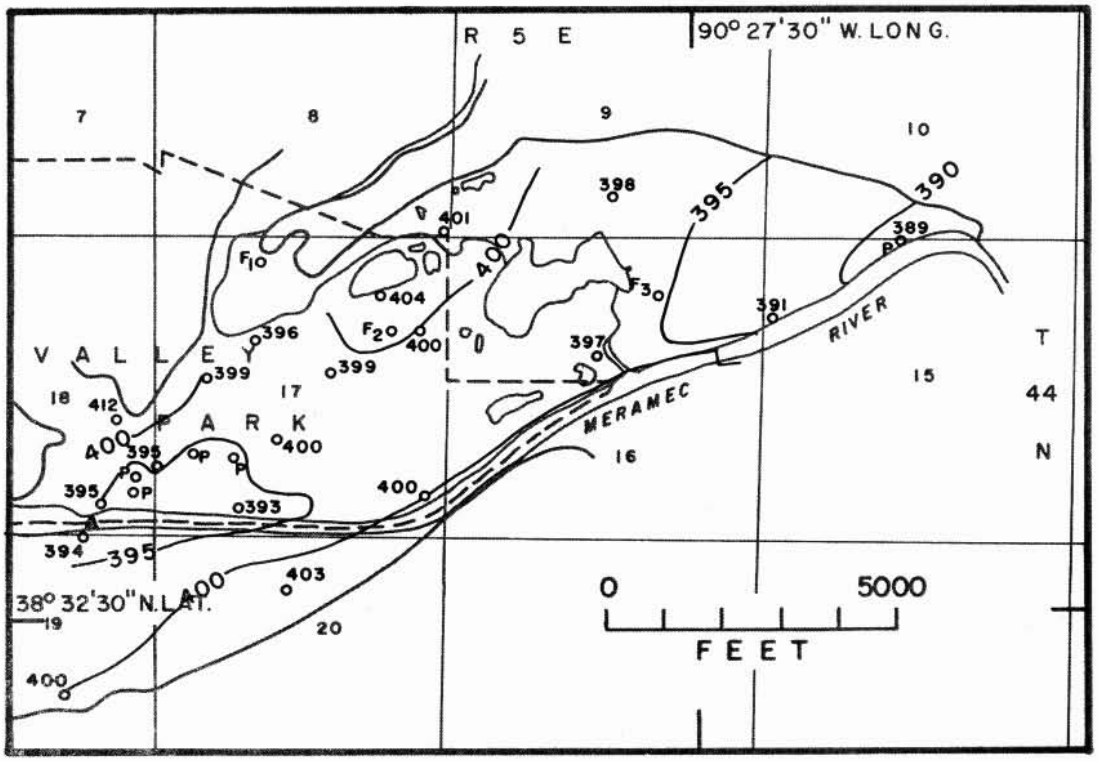
—— 390 ——
Contour shows altitude of potentiometric surface; interval is 5 feet. Datum is mean sea level.

Valley wall

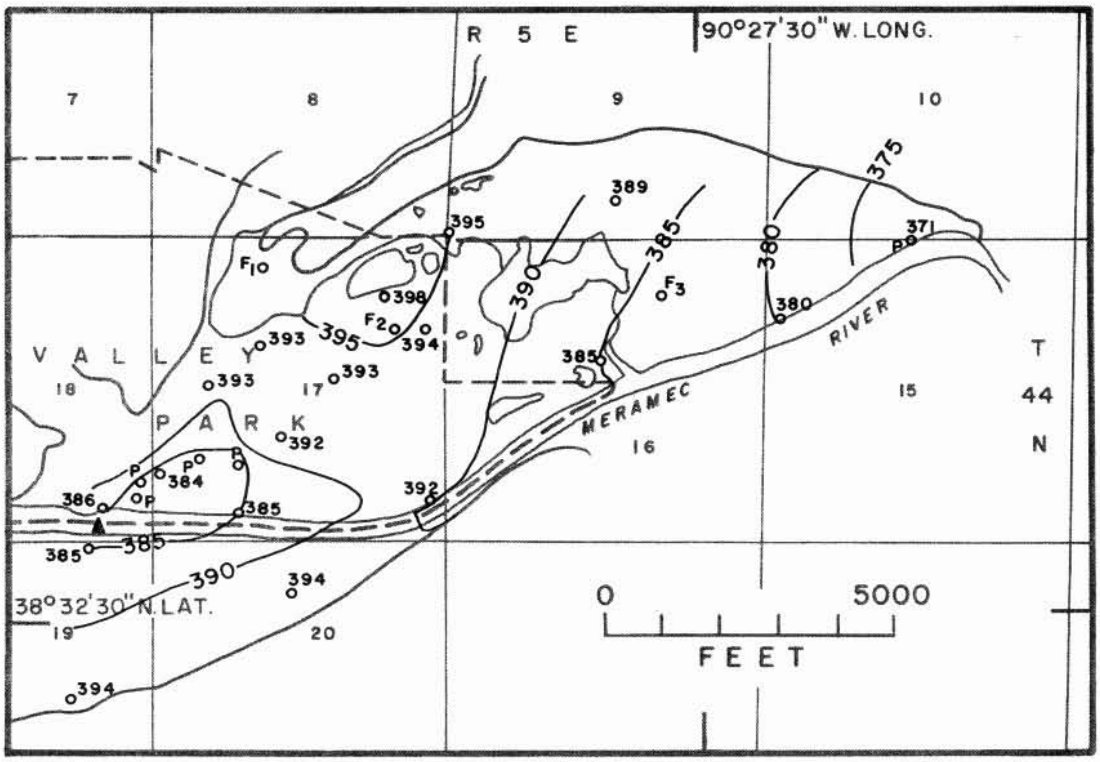
▲
Stream gage

**Figure 10a**

*Location of wells in the Valley Park-Kirkwood area.*




*Potentiometric surface of the Valley Park-Kirkwood area alluvial aquifer:*
Figure 10b (top) May 1970. *Elevation of the river at Valley Park is 402.5 feet.*
Figure 10c (bottom) July 1970. *Elevation of the river at Valley Park is 391 feet.*



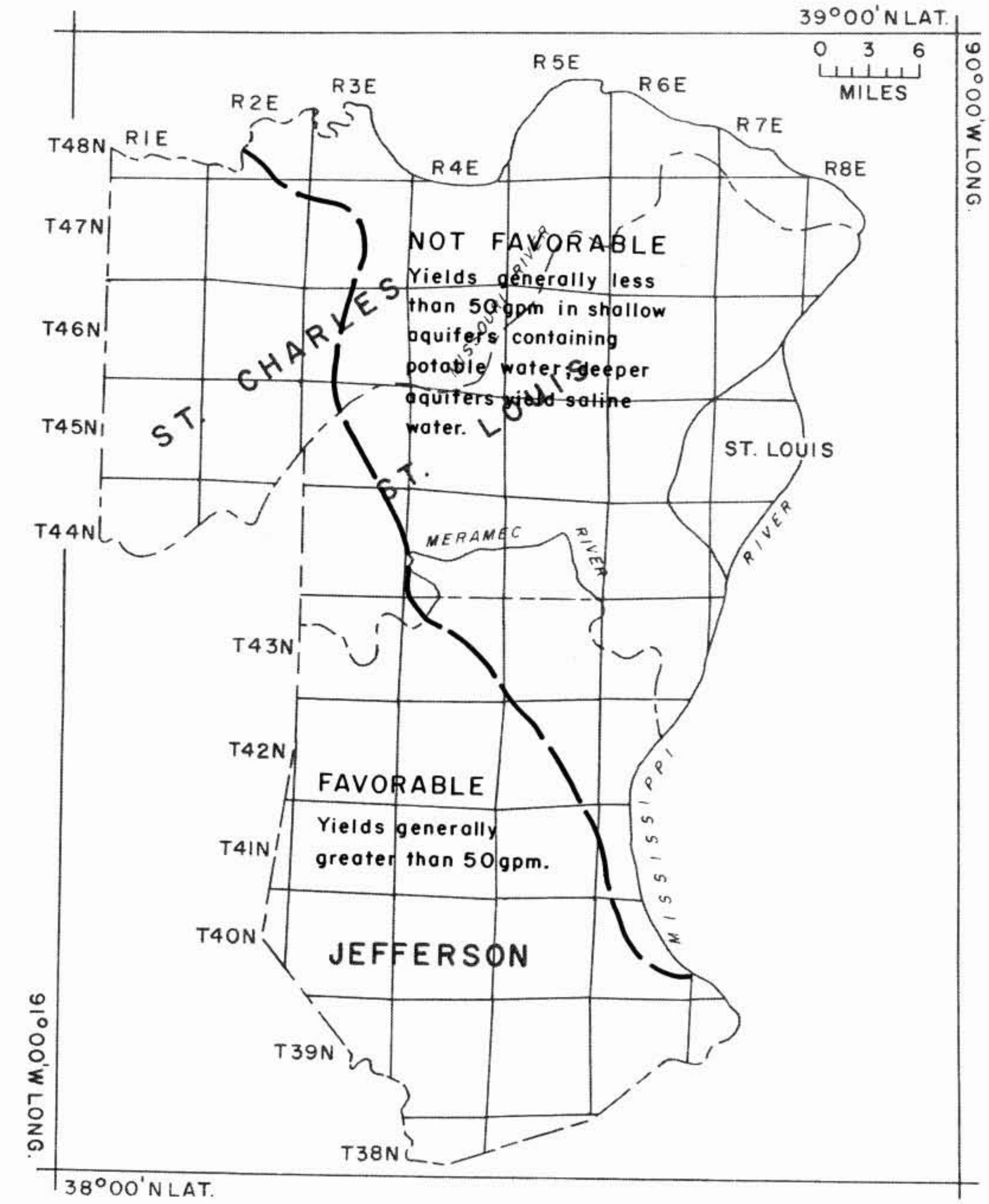



**Figure 11**

*Most favorable area for development of high-yield wells in bedrock aquifers (differentiated by water quality and not by absence of high-yield aquifers).*

## WELL YIELDS AND AQUIFER CHARACTERISTICS

All bedrock units are locally capable of yielding water in varying amounts to wells. Yields of wells are dependent, of course, on such factors as depth, length and diameter of the open hole; formations penetrated; geographic location (p. 10); structural attitude of the rock; and permeability of the aquifers tapped. Because of the stratigraphic complexity of this area and probable interformational movement of the water, it is difficult to define parameters which describe yield capabilities of individual aquifers. It is possible, however, to use data from wells penetrating various aquifer combinations to arrive at conclusions about the more important water-bearing units in the study area.

A reliable measure of the productivity of a well is its specific capacity. This is the discharge of the well expressed as a rate of yield per unit of drawdown, generally in gallons per minute per foot of drawdown.

Specific capacities and yields of wells penetrating aquifers or groups of aquifers are shown in table 2. Higher specific capacities for wells in bedrock are apparent in the western part of the study area and in the south-central part of Jefferson County because higher-yielding units are penetrated by the wells. On the average, wells penetrating Groups 3 and 4 aquifers (St. Peter Sandstone through the Gunter Member of the lower part of the Gasconade Dolomite) had yields significantly higher (100+gpm) than wells finished in aquifer Groups 1 (Post-Maquoketa) or 2 (Kimmswick-Joachim) which were from 3 to 50 gpm. Many wells started in aquifers in Groups 1 or 2 and finished in aquifers in Groups 3 or 4 had better yields than those actually finished in aquifers in Groups 1 or 2. The yields of wells opened only to aquifers in Group 5 (Eminence-Lamotte) were inconsistent, ranging from less than 10 gpm to as much as 400 gpm.

Wells penetrating the St. Peter Sandstone of Group 3 aquifers, the Roubidoux and Gasconade Formations of Group 4 aquifers and the Potosi Dolomite of Group 5 aquifers consistently had higher yields than wells which did not penetrate these units. Figure 11 shows areas where water in these aquifers (or aquifer groups) was acceptable in quality and should be considered for future development when high-yield groundwater supplies are needed.

Yields of 500 gpm have been reported from wells in the Meramec River alluvium. In the Missouri River alluvium, a well in the old Weldon Springs Ordnance Plant well field was pumped at approximately 2,600 gpm for 47 hours during an aquifer test (Emmett and Jeffery, 1968). According to Searcy, Baker and Durum (1952, p. 48), this well field consisted of 13 large-capacity wells on a 344-acre tract which supplied water from the Missouri River alluvium at a rate of more than 44 mgd. Discharge exceeding 3,300 gpm has been reported from irrigation wells in the Mississippi River alluvium.

Specific capacities reported for wells in the Mississippi, Missouri and Meramec River alluvium are given in table 2. Durations of the tests are not known in all instances. However, these values can serve as an indication of the productivity of wells in the alluvial aquifers.

Generally, high specific capacities indicate an aquifer with high transmissivity while low specific capacities indicate an aquifer with a low transmissivity.

Two characteristics governing the value of an aquifer as a source of water are its ability to store and to transmit water. These two values can be measured by aquifer tests.

For artesian (confined) aquifers, the storage coefficient may range from 0.00001 to 0.001. The storage coefficients of water-table aquifers range from about 0.05 to 0.30.

The coefficients of storage and transmissivity were determined at two sites. These values are presented in table 2. The transmissivities at the two sites are virtually the same but the coefficients of storage indicate water-table conditions at the Weldon Spring site and artesian conditions at the St. Charles site. Available well logs and water-level measurements indicate that artesian or leaky artesian conditions prevail throughout most of the Mississippi River alluvium.

Results obtained from these two tests are indicators of the hydrologic characteristics of the alluvial aquifers. Any large-scale development of groundwater resources should be based on additional tests.

Table 2

Summary of well data for the St. Louis area

| City or subdivision | Owner | Well location | Depth (feet) | Well diameter (inches) | Date of test | Pumping rate (gpm) | Duration of test (hours) | Specific capacity (gpm/ft drawdown) | Draw-down (feet) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Bedrock aquifers | | | | | | |
| City of De Soto | | 39-4-3add | 800 | 10 | Aug. 1954 | 465 | 4 | 9.3 | 50 | Potosi Dolomite (Group 5) |
| - | Burt Manor Nursing Home | 39-5-20dda | 510 | 6 | - | 26 | 6 | 0.73 | 36 | Lower part of Gasconade Dolomite Eminence Dolomite (Groups 4 & 5) |
| - | Robert Schroeder | 39-5-31dba | 285 | 6 | Jan. 1960 | 18 | 1 | 0.09 | 200 | Jefferson City-Roubidoux (Group 4) |
| - | Blanche Combs Trailer Court | 40-3-32 | 1050 | 6 | 1967 | 60 | 6 | 1.33 | 45 | Bonneterre-Lamotte (Group 5) |
| - | Jefferson County Memorial Hospital | 40-6-17bdc | 750 | 8 | 1955 | 88 | 24 | 0.44 | 176 | Cotter-Lower part of Gasconade (Group 4) |
| - | Mississippi River Fuel Corp. River Cement | 40-6-22adc | 1000 | 8 | - | 82 | 8 | 0.44 | 187 | St. Peter-Upper part of Gasconade (Groups 3 & 4) |
| - | Dow Chemical Co. | 41-6-18dac | 390 | - | 1956 | 140 | 12 | 0.98 | 143 | St. Peter-Everton (Group 3) |
| City of Cedar Hill | - | 42-3-25abb | 902 | 8 | May 1953 | 50 | - | 0.24 | 212 | Cotter-Eminence (Groups 4 & 5) |
| - | Jefferson County Water District No. 9 | 42-5-31bcc | 1200 | 8 | 1967 | 130 | 24 | 1.63 | 80 | Powell-Roubidoux (Group 4) |
| - | Beaumont Boy Scout Reservation | 43-4-2bca | 540 | 8 | 1950 | 50 | 24 | 0.44 | 113 | Plattin-St. Peter (Groups 2 & 3) |
| Briar-Cliff Estates | Leonard Small Realty Co. | 43-4-12bdc | 675 | 6 | Sept. 1959 | 23 | 24 | 0.21 | 107 | Kimmswick-Everton (Groups 2 & 3) |
| - | Babler State Park | 45-3-28bbd | 1072 | 10 | Aug. 1940 | 182 | 24 | 1.61 | 113 | Joachim-St. Peter (Groups 2 & 3) |
| - | C. Kaimann | 46-7-20 | 655 | 8 | Feb. 1936 | 120 | 4 | 0.89 | 135 | Ste. Genevieve-Burlington (Group 1) |
| - | Atlas Powder Co. | 46-3-28ddd | 811 | 8 | Feb. 1941 | 13 | 3 | 0.07 | 200 | Kimmswick-St. Peter (Groups 2 & 3) |
| Lake St. Louis | - | 47-2-27 | 1375 | 8 | Mar. 1970 | 140 | 4 | 0.76 | 193 | Plattin-Roubidoux (Groups 2, 3, & 4) |
| City of O'Fallon | Well No. 3 | 47-3-20ada | 1500 | 8 | Oct. 1960 | 132 | 2 | 2.64 | 50 | Kimmswick-Upper part of Gasconade (Groups 2, 3, & 4) |
| - | Monsanto Chemical Co. | 47-3-23ccc | 1397 | 10 | April 1967 | 183 | 24 | 0.53 | 348 | Kimmswick-Roubidoux (Groups 2, 3, & 4) |
| City of O'Fallon | Well No. 1 | 47-3-29aaa | 833 | 8 | Sept. 1940 | 55 | 24 | 0.25 | 221 | Kimmswick-St. Peter (Groups 2 & 3) |
| | | | | Mississippi River alluvium | | | | | | |
| Portage des Sioux | Portage des Sioux | 48-6-15bcb | 116 | 8 | | 500 | 4½ | 48 | 10.5 | 10 screen |
| - | Blue Wing | 47-4-7cbd | 100 | 16 | | 2000 | | | | |
| - | Whistling Wing | 47-4-11dba | 80 | | | 1230 | | 85 | 14.6 | |
| - | Lindberg & Kenney | 48-3-35cbd | 106 | 16 | | 2249 | | 80 | 28 | |
| - | Oro Farm | 47-3-4adc | 92 | | | 1690 | | 105 | 16 | |
| - | Hermitage Club | 47-3-12ada | 106 | 16 | | 1750 | | 175 | 10 | |
| - | Webfoot Club | 47-3-12cdd | 95 | 14 | | 1900 | | 83 | 23 | 32-ft screen |
| St. Charles | St. Charles | 47-4-24 | 107 | | | | | | | T=36,180 cubic feet per day per foot S=.0004 |
| - | Portage Farms | 48-5-23dad | 107 | 26 | Sept. 1963 | 1160 | | 102 | 11.4 | |
| | | | | Missouri River alluvium | | | | | | |
| - | Mr. Ambo | 46-4-25bbd | 102 | 16 | 1963 | 840 | 2 | 168 | 5 | 32-ft screen. Well not pumped at steady rate. |
| - | Mr. Smittle | 46-5-17 | 96 | 12 | | 600 | | | | 32-ft screen |
| - | Mr. Twillman | 46-4-28 | 83 | 12 | | 900 | | 69 | 13 | |
| - | Weldon Springs Ordnance Plant | 45-3-18bcc | 107 | 15 | 1967 | 2650 | 47 | | | Aquifer test. T=36,180 cubic feet per day per foot S=0.2 |
| | | | | Meramec River alluvium | | | | | | |
| Valley Park | Valley Park | 44-5-18dda$_1$ | 63 | 18 | Aug. 1949 | 504 | 24 | 72 | 7 | 15 ft of 18-inch screen |
| Valley Park | Valley Park | 44-5-18dda$_2$ | 63 | 18 | July 1949 | 504 | 24 | 36 | 14 | 15 ft of 18-inch screen. Yield has increased to 47 gpm/ft after treatment for capacity loss. |
| Valley Park | Absorbent cotton | 44-5-17cdb | 63 | 16 | May 1957 | 500 | 12 | 83 | 6 | 15 ft of 16-inch screen gravel pack. |
| Valley Park | Ashland Chemical | 44-5-17cbd | 59 | 16 | Oct. 1959<br>June 1964 | 503<br>554 | -<br>- | 102<br>111 | 5<br>5 | 15 ft of 16-inch screen gravel pack. |
| Kirkwood | Kirkwood No. 1<br>Kirkwood No. 2 | 44-5-15<br>44-5-15 | 37<br>42 | 18<br>18 | Dec. 1926<br>Nov. 1927 | 300<br>250 | 10<br>10 | 60<br>83 | 5<br>3 | 18 ft of 18-inch screen<br>20 ft of 18-inch concrete screen. |

## CHEMICAL QUALITY OF GROUND WATER

Most bedrock wells are constructed with several aquifers open to the well and, for this reason, it is not feasible to sample water from individual aquifers to determine their representative water-quality characteristics. Therefore, the discussion of chemical quality of water from bedrock will be by the five aquifer groups shown on figure 7. Quality of water from alluvial deposits will be discussed as Meramec River alluvium and as Mississippi-Missouri River alluvium. Only analyses of water from wells depicted on logs in the Missouri Geological Survey files were used in this study.

The chemical quality of ground water in the study area is quite variable, ranging in dissolved-solids content from 122 to 17,500 mg/l (milligrams per liter), with the water varying from a calcium-magnesium bicarbonate to a sodium chloride, sodium sulfate, or a sodium bicarbonate type. At lower concentrations of dissolved solids, the calcium-magnesium-bicarbonate type of water generally is predominant and, as the dissolved-solids content of the water increases, the type of water is variable depending upon the source. At higher concentrations of dissolved solids the water is a sodium-chloride type.

The source and significance of dissolved mineral constituents and properties of water are summarized in table 3. The values that were equal to or less than found in 75 and 50 percent of the samples from each aquifer group and from the alluvial deposits of the major streams are given in tables 4 and 5. Differences in the concentrations of various constituents are apparent, indicating certain factors which control water quality in the study area.

The principal factors affecting groundwater quality in the area are the complex interrelations imposed by the lithology of the rock units; permeability of the rock units; the controls on water movement exerted by the geologic structure; the length of time water has been in the aquifer and the distance it has moved from the recharge area; the degree of flushing of entrapped saline water (connate water) from the rock units; and, in local areas, the works of man.

The structural attitude of rock units in the St. Louis area exerts a pronounced effect on ground water recharge, discharge, and quality. Anticlinal features such as the Eureka-House Springs anticline shown on figure 6 tend to be areas of recharge due to secondary permeability developed at their crests by fracturing and jointing. The synclines probably act as traps for mineralized water, and flushing progresses more slowly than elsewhere. Waters in these synclinal areas tend to be of poorer quality than waters from areas where more complete flushing has taken place. Structure contour maps and cross-sections of the area seem to substantiate the presence of synclinal traps in the Valley Park area and in T. 42 and 43 N., R. 6 E., in southeastern St. Louis County and northeastern Jefferson County. Also, movement of highly mineralized water from deeper horizons up into shallower zones through old abandoned wells is probably occurring in the Valley Park area.

Faults (fractures along which there has been movement of the two sides relative to one another) can act either as barriers to groundwater flow, when aquifers are faulted against impervious beds or the rocks have been recemented, or as open conduits for water if the rock is broken and fractured adjacent to the fault. When the fault zone is impervious, complete flushing of connate water in the aquifer might not be accomplished. If the fault zone is open, complete flushing of connate water takes place, and the more rapid circulation of water removes much of the soluble material. Fault zones which are accompanied by intense rock deformation, such as the area in southwestern Jefferson County in T. 39 N., R. 3 E., and 4, are locally important recharge areas. The Maxville fault in T. 43 N., R. 5 E., (fig. 6) acts as a barrier to the movement of water and retards flushing in the aquifer.

In addition to the physical constraints that affect groundwater quality, man unfortunately creates many of his own problems. Effluents from improperly constructed septic tanks or from areas where the concentration of septic tanks is too great for the absorptive capabilities of the soil cover, and leakage from improperly constructed or improperly located sewage lagoons moves into the groundwater reservoir and contaminates the ground water. Drainage from improperly operated or improperly located sanitary landfills may also add large quantities of contaminants to the groundwater reservoir.

The generalized groundwater-quality areas shown in plate 2, are based on a dissolved-solids content of less than 500 mg/l in or above the

Table 3

SOURCE AND SIGNIFICANCE OF DISSOLVED MINERAL CONSTITUENTS AND PROPERTIES OF WATER

| Constituent or property | Source or cause | Significance |
|---|---|---|
| Silica ($SiO_2$) | Dissolved from practically all rocks and soils, commonly less than 30 mg/l High concentrations, as much as 100 mg/l, generally occur in highly alkaline waters. | Forms hard scale in pipes and boilers. Carried over in steam of high-pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softeners. |
| Iron (Fe) | Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment. More than 1 or 2 mg/l of soluble iron in surface waters generally indicates acid wastes from mine drainage or other sources. | More than about 0.3 mg/l stains laundry and utensils reddish brown. Objectionalbe for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. USPHS (1962) drinking-water standards state that iron should not exceed 0.3 mg/l. Larger quantities cause unpleasant taste and favor growth of iron bacteria. |
| Manganese (Mn) | Dissolved from some rocks and soils. Not so common as iron. Large quantities often associated with high iron content and acid waters. | Same objectionable features as iron. Causes dark brown or black stain. USPHS (1962) drinking-water standards state that manganese should not exceed 0.05 mg/l. |
| Calcium (Ca) and magnesium (Mg) | Dissolved from practically all rocks and soils, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water. | Cause most of the hardness and scale-forming properties of water; soap consuming (see Hardness). Waters low in calcium and magnesium desired in electroplating, tanning, and dyeing and in textile manufacturing. |
| Sodium (Na) and potassium (K). | Dissolved from practically all rocks and soils. Found also in ancient brines, sea water, industrial brines, and sewage. | Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers, and a high sodium content may limit the use of water for irrigation. |
| Bicarbonate ($HCO_3$) and carbonate ($CO_3$) | Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite. | Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium they cause carbonate hardness. |
| Sulfate ($SO_4$) | Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in mine waters and some industrial wastes. | Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives a bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. USPHS (1962) drinking-water standards recommend that the sulfate content should not exceed 250 mg/l. |
| Chloride (Cl) | Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial wastes. | In large amounts in combination with sodium gives salty taste to water. In large quantities increases the corrosiveness of water. USPHS (1962) drinking-water standards recommend that the chloride content not exceed 250 mg/l. |
| Fluoride (F) | Dissolved in small to minute quantities from most rocks and soils. Added to many waters by fluoridation of municipal supplies. | Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth depending on the concentration of fluoride, the age of the child, the amount of water consumed, and the susceptibility of the individual. The maximum concentration of fluoride recommended by the USPHS (1962) varies with the annual average of maximum daily air temperatures and ranges downward from 1.7 mg/l for an average maximum daily temperature of 10.0$^{\circ}$ C to 0.8 mg/l for an average maximum daily temperature of 32.5$^{\circ}$C. Optimum concentrations for these ranges are from 1.2 to 0.7 mg/l. |

**Table 3** (continued) . . . . .

| Constituent or property | Source or cause | Significance |
|---|---|---|
| Nitrate ($NO_3$) | Decaying organic matter, legume plants, sewage, nitrate fertilizers and nitrates in soils. | Concentration much greater than the local average may suggest pollution. USPHS (1962) drinking-water standards suggest a limit of 45 mg/l. Waters of high nitrate content have been reported to be the cause of methemoglobinemia (an often fatal disease in infants) and therefore should not be used in infant feeding. Nitrate has been shown to be helpful in reducing the intercrystaline cracking of boiler steel. It encourages the growth of algae and other organisms which may cause odor problems in water supplies. |
| Dissolved solids | Chiefly mineral constituents dissolved from rocks and soils. | USPHS (1962) drinking-water standards recommend that the dissolved solids should not exceed 500 mg/l. However, 1,000 mg/l is permitted under certain circumstances. Waters containing more than 1,000 mg/l of dissolved solids are unsuitable for many purposes. |
| Hardness as $CaCO_3$ | In most waters, nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals also cause hardness. | Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called noncarbonate hardness. Waters of hardness up to 60 mg/l are considered soft; 61-120 mg/l moderately hard; 121-180 mg/l hard; more than 180 mg/l very hard. |
| Specific conductance (micromhos at 25°C). | Mineral content of the water. | Indicates degree of mineralization. Specific conductance is a measure of the capacity of the water to conduct an electric current. It varies with the concentrations and degree of ionization of the constituents, and with temperature. |
| Hydrogen-ion concentration (pH) | Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise the pH. | A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 denote increasing acidity. pH is a measure of the activity of hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline water may also attack metals. |
| Color | Yellow-to-brown color of some water usually is caused by organic matter extracted from leaves, roots, and other organic substances. Color in water also results from industrial wastes and sewage. | Water for domestic and some industrial uses should be free from perceptible color. Color in water is objectionable in food and beverage processing and many manufacturing processes. |
| Temperature | Climatic conditions, use of water as a cooling agent, industrial pollution. | Affects usefulness of water for many purposes. Most users desire water of uniformly low temperature. Seasonal fluctuations in temperature of surface waters are comparatively large depending on the volume of water. |
| Suspended sediment | Erosion of land and stream channels. Quantity and particle-size gradation affected by many factors such as form and intensity of precipitation, rate of runoff, stream channel and flow characteristics, vegetal cover, topography, type and characteristics of soils in drainage basin, agricultural practices, and some industrial and mining activities. Largest concentrations and loads occur during periods of storm runoff. | Sediment must generally be removed by flocculation and filtration before water is used by industry or municipalities. Sediment deposits reduce the storage capacity of reservoirs and lakes and clog navigable stream channels and harbors. Particle-size distribution is a factor controlling the density of deposited sediment and is considered in the design of filtration plants. Sediment data are of value in designing river-development projects, in the study of biological conditions and fish propagation, and in programs of soil conservation and watershed management. |

[1] "Public Health Service Drinking Water Standards," revised 1962, apply to drinking water and water-supply systems used by carriers and others subject to Federal quarantine regulations.

Table 4

Comparison of 75 percentile values of chemical constituents dissolved in water from each aquifer group

[data in milligrams per liter, or as indicated]

| Constituent | Aquifers | | | | | Alluvium Meramec River | Alluvium Mississippi and Missouri Rivers |
|---|---|---|---|---|---|---|---|
| | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | | |
| Silica ($SiO_2$)------- | 12 | 8.5 | 9.4 | 8.9 | 9.6 | 12 | 30 |
| Iron (Fe)----------- | .22 | .52 | .50 | .25 | .31 | 2.2 | 9.4 |
| Manganese (Mn)------ | ---- | ---- | ---- | ---- | ---- | .85 | .95 |
| Calcium (Ca)-------- | 97 | 105 | 94 | 95 | 120 | 86 | 133 |
| Magnesium (Mg)------ | 49 | 51 | 40 | 51 | 58 | 25 | 34 |
| Sodium (Na)--------- | 350 | 80 | 35 | 40 | 166 | 34 | 16 |
| Potassium (K)------- | ---- | ---- | ---- | 7.8 | ---- | 2.8 | 5.0 |
| Bicarbonate plus carbonate ($HCO_3+CO_3$). | 515 | 397 | 380 | 420 | 396 | 266 | 528 |
| Sulfate ($SO_4$)------- | 92 | 88 | 36 | 71 | 48 | 65 | 71 |
| Chloride (Cl)------- | 49 | 32 | 38 | 45 | 370 | 56 | 7.5 |
| Fluoride (F)-------- | 3.0 | 1.4 | .7 | .7 | .1 | .1 | .4 |
| Nitrate ($NO_3$)------- | 2.5 | 1.9 | 2.8 | 1.5 | .3 | 2.3 | 1.1 |
| Dissolved solids (residue at 180°C). | 820 | 621 | 475 | 610 | 770 | 476 | 596 |
| Hardness as $CaCO_3$--- | 435 | 430 | 345 | 440 | 450 | 324 | 513 |
| Specific conductance (micromhos at 25°C). | ---- | ---- | ---- | ---- | ---- | 806 | 884 |
| pH----------------- | ---- | ---- | ---- | ---- | ---- | 7.7 | 8.0 |

aquifer group indicated by the number designation of the area. For example, a well drilled in area 3 could expect potable water in all aquifers through the St. Peter Sandstone and Everton Formation.

### BEDROCK AQUIFERS

#### GROUP 1 (POST-MAQUOKETA) AQUIFERS

Water from Group 1 aquifers varies from a calcium-magnesium-bicarbonate type to a sodium-sulfate, sodium-bicarbonate, or a sodium-chloride type. The dissolved-solids content is quite variable, ranging from 246 to 6,880 mg/l. The water is generally low in iron and very hard (Hem, 1970, p. 225). Slightly more than 75 percent of the wells sampled yielded water containing less than 0.3 mg/l of iron. Hardness of water from most of the wells was greater than 180 mg/l. Fluoride content of the water is relatively high. In 50 percent of the samples, the fluoride content was greater than 1.4 mg/l. The analyses of water from 99 wells are summarized in table 6, and selected analyses of water from Group 1 aquifers are given in appendix 2. Locations of the wells are shown on plate 1 and some analyses are shown graphically on plate 2.

The data given in table 6 indicate that just over 50 percent of the wells sampled yielded potable water. These wells are, for the most part, near the outcrop line of Meramecian Series rocks (St. Louis, Salem, and Warsaw Formations) of Mississippian age, and, based upon the 25 percentile values, they yield predominantly calcium-magnesium-bicarbonate type of water. The higher dissolved-solids contents in water from Group 1 aquifers are from an area just north and northwest of the city of St. Louis in St.

Louis County, and in extreme southeastern St. Louis County. Water in these areas generally is a sodium-chloride type, but it may also contain large amounts of calcium and sulfate. Variations in the predominant chemical characteristics between the calcium-magnesium-bicarbonate type and the sodium-chloride type are presumably related to the effects of geologic structure, the movement of water from overlying or underlying formations into Group 1 aquifers, and to the presence of certain minerals in the parent rock.

Waters having a high sulfate content are, for the most part, limited to the area underlain by rocks of Pennsylvanian age. These rocks comprise shales, sandstones, and siltstones that locally have minor amounts of pyrite and gypsum. These fine-grained rocks are relatively impermeable; however, over a large area, they could yield enough seepage to explain some of the sulfate anomalies in the study area. In northeastern St. Louis County, high concentrations of sulfate coincide with the Cheltenham syncline (Fenneman, 1911, fig. 5), and, according to Trapp (1961), the sulfate/chloride ratios indicate that water with a higher sulfate content is moving upward from lower stratigraphic horizons. A persistent zone at the base of the St. Louis Limestone has thin stringers of gypsum that could contribute minor amounts of sulfate to the ground water in this part of the study area (Owens, 1960).

In southeastern St. Louis County, the chemical character of the water changes from a predominantly calcium-magnesium-bicarbonate type to a sodium-bicarbonate type, and, farther downdip, to a sodium-chloride type. The sodium-bicarbonate type of water

Table 5

Comparison of 50 percentile values of chemical constituents dissolved in water from each aquifer group

[data in milligrams per liter, or as indicated]

| Constituent | Aquifers | | | | | Alluvium Meramec River | Alluvium Mississippi and Missouri Rivers |
|---|---|---|---|---|---|---|---|
| | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | | |
| Silica ($SiO_2$) | 8.6 | 6.2 | 8.4 | 7.2 | 8.0 | 11 | 26 |
| Iron (Fe) | .15 | .15 | .17 | .11 | .19 | .75 | 5.2 |
| Manganese (Mn) | ---- | ---- | ---- | ---- | ---- | .76 | .75 |
| Calcium (Ca) | 71 | 66 | 74 | 78 | 68 | 66 | 106 |
| Magnesium (Mg) | 37 | 36 | 30 | 39 | 38 | 20 | 26 |
| Sodium (Na) | 80 | 27 | 15 | 15 | 7.6 | 21 | 11 |
| Potassium (K) | ---- | ---- | ---- | 4.1 | ---- | 1.8 | 3.9 |
| Bicarbonate plus carbonate ($HCO_3$+$CO_3$). | 440 | 352 | 347 | 350 | 342 | 212 | 449 |
| Sulfate ($SO_4$) | 30 | 38 | 20 | 37 | 23 | 45 | 26 |
| Chloride (Cl) | 12 | 11 | 9.0 | 10 | 6.7 | 29 | 4.1 |
| Fluoride (F) | 1.4 | .7 | .4 | .2 | .1 | .0 | .2 |
| Nitrate ($NO_3$) | .9 | .6 | .6 | .4 | .2 | .4 | .2 |
| Dissolved solids (residue at 180°C). | 480 | 418 | 390 | 430 | 392 | 351 | 476 |
| Hardness as $CaCO_3$ | 360 | 313 | 302 | 350 | 353 | 247 | 402 |
| Specific conductance (micromhos at 25°C). | ---- | ---- | ---- | ---- | ---- | 593 | 773 |
| pH | ---- | ---- | ---- | ---- | ---- | 7.8 | 7.6 |

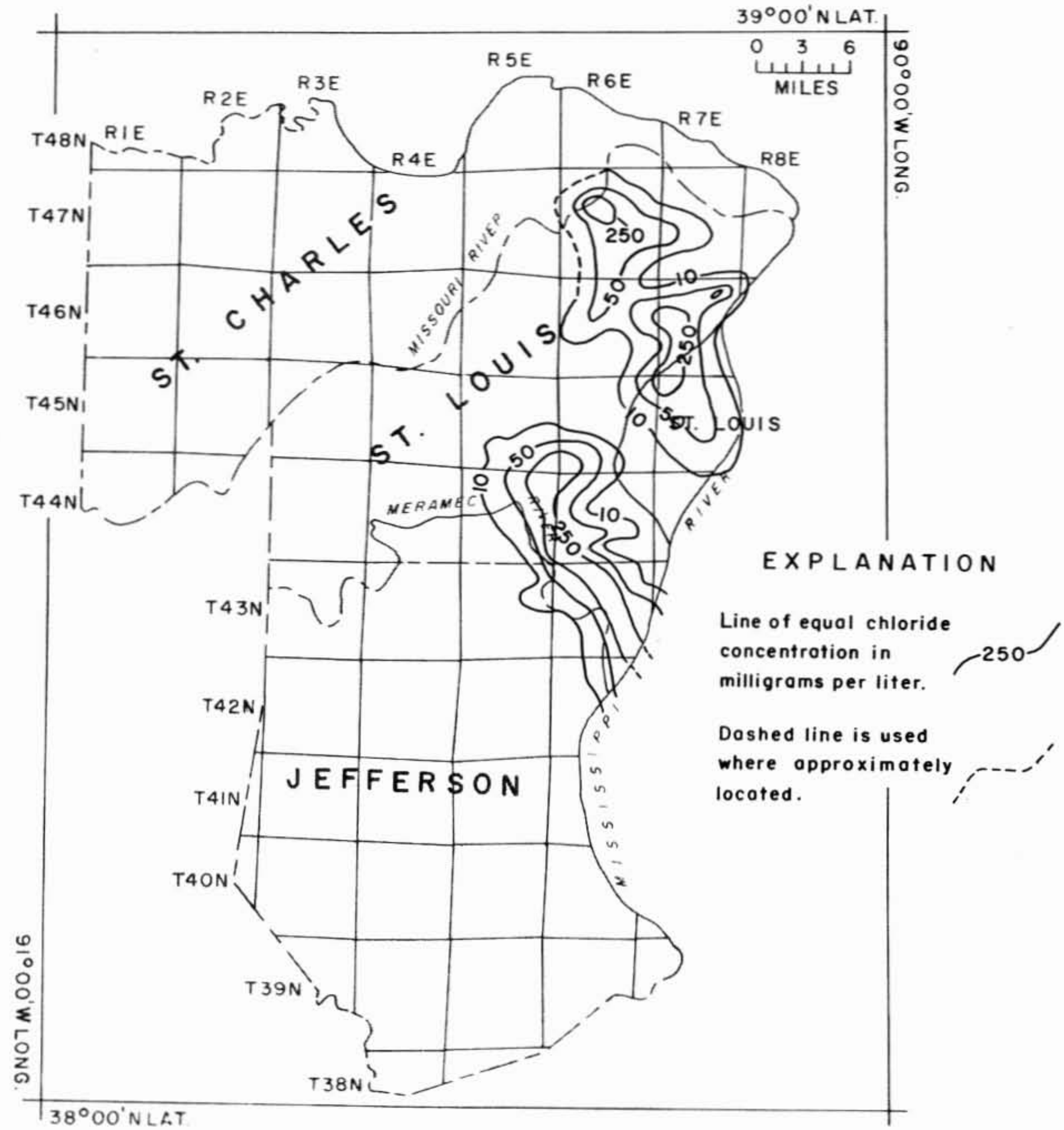



**Figure 12**

*Distribution of chloride in Group 1 (Post-Maquoketa) aquifers.*

evidently is a result of base-exchange – a process in which calcium and magnesium ions in the water are replaced by sodium ions. The minimum values shown on table 6 for calcium and magnesium are for analyses of water from this area.

Both of these areas of high dissolved solids coincide with synclinal or anticlinal structures developed in the rocks. The area in eastern St. Louis County coincides with the northern part of the Cheltenham syncline, the Florissant dome and the Twelfth Street anticline, and the area in southeastern St. Louis County coincides with a troughlike depression which is apparent on structural maps prepared by Trapp (1961). Figure 12 is a map showing the generalized distribution of chloride in Group 1 aquifers. It is possible that groundwater circulation is extremely poor in these areas and the high chloride water has not been flushed from the aquifers. However, it is more probable that mineralized water has moved into some of the structures from deeper horizons or from adjacent gas- and oil-bearing rocks.

High concentrations of iron were found in water from many areas (fig. 13). Although the reasons for the high iron content are not known, the same form of geochemical control is probably responsible for all of the high values in the study area.

The high fluoride values in water from this group could result from solution of fluorite in the aquifers. However, increases in fluoride concentration have been noted in other parts of the State accompanying encroachment of saline water.

#### GROUP 2 (KIMMSWICK-JOACHIM) AQUIFERS

Water from wells that bottom in Group 2 aquifers range in dissolved-solids content from 207 to 17,500 mg/l, with 75 percent of the samples containing less than 621 mg/l (table 7). At the higher levels of dissolved solids, the waters are a sodium-chloride type. The waters generally are low in iron content; 68 percent of the samples analyzed contained less than 0.3 mg/l. Hardness of the water ranges from 128 to 1,270 mg/l. The fluoride content of 75 percent of the samples analyzed was less than 1.4 mg/l. The analyses of water from 57 wells are summarized in table 7. Twenty of these analyses were from wells that are open only to Group 2 aquifers. The remainder of the analyses are from wells open to Group 1 and Group 2 aquifers. Selected analyses of water from Group 2 aquifers are given in

### Table 6

### Maximum, minimum, and 25, 50, 75 percentile values for constituents in water from Group 1 (post-Maquoketa) aquifers[a]

[data in milligrams per liter]

| Constituent | Maximum | Percent of Samples 75 | 50 | 25 | Minimum |
|---|---|---|---|---|---|
| Silica ($SiO_2$)------ | 38 | 12 | 8.6 | 5.8 | 0.1 |
| Iron (Fe)---------- | 13 | 0.22 | 0.15 | 0.12 | 0.02 |
| Calcium (Ca)------- | 1,380 | 97 | 71 | 42 | 3.6 |
| Magnesium (Mg)----- | 131 | 49 | 37 | 25 | 1.1 |
| Sodium (Na)-------- | 2,400 | 350 | 80 | 22 | 7.6 |
| Bicarbonate plus carbonate ($HCO_3$+$CO_3$). | 857 | 515 | 440 | 350 | 220 |
| Sulfate ($SO_4$)------ | 1,290 | 92 | 30 | 18 | 0.2 |
| Chloride (Cl)------ | 3,420 | 49 | 12 | 5.5 | 0.5 |
| Fluoride (F)------- | 13 | 3.0 | 1.4 | .3 | .0 |
| Nitrate ($NO_3$)------ | 77 | 2.5 | .9 | .0 | .0 |
| Dissolved solids (residue at 180°C). | 6,880 | 820 | 480 | 395 | 246 |
| Hardness as $CaCO_3$ -- | 3,950 | 435 | 360 | 220 | 14 |

a/ Data based on analyses from 99 wells.

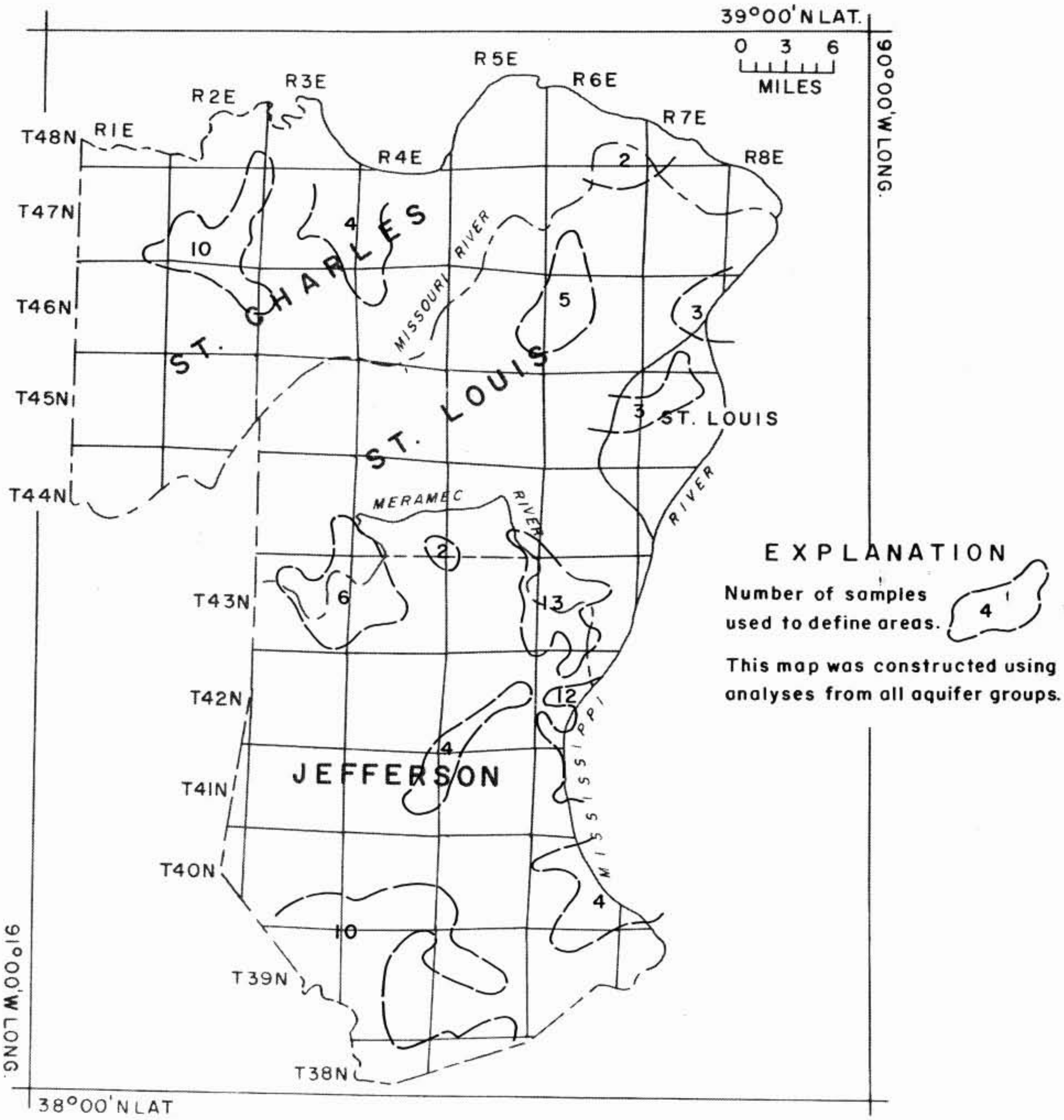



Figure 13

*Areas in which iron concentrations in ground water from bedrock aquifers are in excess of 0.3 milligrams per liter.*

Table 7

Maximum, minimum, and 25, 50, 75 percentile values for constituents in water from Group 2 (Kimmswick-Joachim) aquifers[a]

[Data in milligrams per liter]

| Constituent | Maximum | Percent of Samples 75 | 50 | 25 | Minimum |
|---|---|---|---|---|---|
| Silica ($SiO_2$)------ | 27 | 8.5 | 6.2 | 4.4 | 1.2 |
| Iron (Fe)---------- | 34 | .52 | .15 | .09 | .01 |
| Calcium (Ca)------- | 279 | 105 | 66 | 46 | 12 |
| Magnesium (Mg)----- | 188 | 51 | 36 | 30 | 12 |
| Sodium (Na)-------- | 5,960 | 80 | 27 | 12 | 4.4 |
| Bicarbonate plus carbonate ($HCO_3$+$CO_3$). | 523 | 397 | 352 | 310 | 141 |
| Sulfate ($SO_4$)------ | 1,320 | 88 | 38 | 21 | 1.6 |
| Chloride (Cl)------ | 10,000 | 32 | 11 | 4.6 | 2.2 |
| Fluoride (F)------- | 3.5 | 1.4 | .7 | .3 | 0 |
| Nitrate ($NO_3$)------ | 13 | 1.9 | .6 | .1 | 0 |
| Dissolved solids (residue at 180°C). | 17,000 | 621 | 418 | 344 | 207 |
| Hardness as $CaCO_3$-- | 1,270 | 430 | 313 | 255 | 128 |

a/ Data based on analyses from 57 wells.

appendix 2. Locations of the wells sampled are shown on plate 1, and a few analyses are shown graphically on plate 2.

Approximately 64 percent of the wells sampled in Group 2 aquifers yielded potable water. These potable waters generally are a calcium-magnesium-bicarbonate type, but a comparison of the 50 and 75 percentile values in table 7 shows significant increases in sodium, sulfate, and chloride with higher dissolved-solids content, indicating that the chemical character of the water is changing to a sodium-sulfate or sodium-chloride type.

Water from wells adjacent to the Meramec River in T. 44 N., R. 4 and 5 E., in the Valley Park area, and in T. 42 N., R. 6 E., in Jefferson County, had a higher dissolved-solids content. The wells in the Valley Park area are in a synclinal structure that may still contain connate water. Some of the mineralized water is moving from deeper horizons, either through natural fractures or through abandoned well bores. The area in Jefferson County is in the vicinity of the Maxville fault and it may not be completely flushed of connate water. Wells in areas to the north and northeast where Group 2 aquifers are more deeply buried undoubtedly yield saline water. Figure 14 shows the generalized distribution of chloride in Group 2 aquifers.

#### GROUP 3 (ST. PETER-EVERTON) AQUIFERS

The chemical characteristics of water given here represent a composite of waters from the St. Peter Sandstone and Everton Formation and from the overlying aquifer groups. Of the 63 analyses of water from wells bottoming in aquifer Group 3, one well derived its water solely from this group. The location of the wells sampled are shown on plate 1, and selected analyses are shown graphically on plate 2. Because of the mixing of water from the different aquifer groups, the chemical characteristics shown for Group 3 water are similar in many respects to those for the overlying groups. However, some differences do exist. The summary of analytical data in table 8 shows the water to be generally a calcium-magnesium-bicarbonate type. Dissolved-solids content ranges from 264 to 7,270 mg/l, with 75 percent of the samples containing less than 475 mg/l. Hardness of the water ranges from 30 to 1,420 mg/l, and the iron and fluoride contents

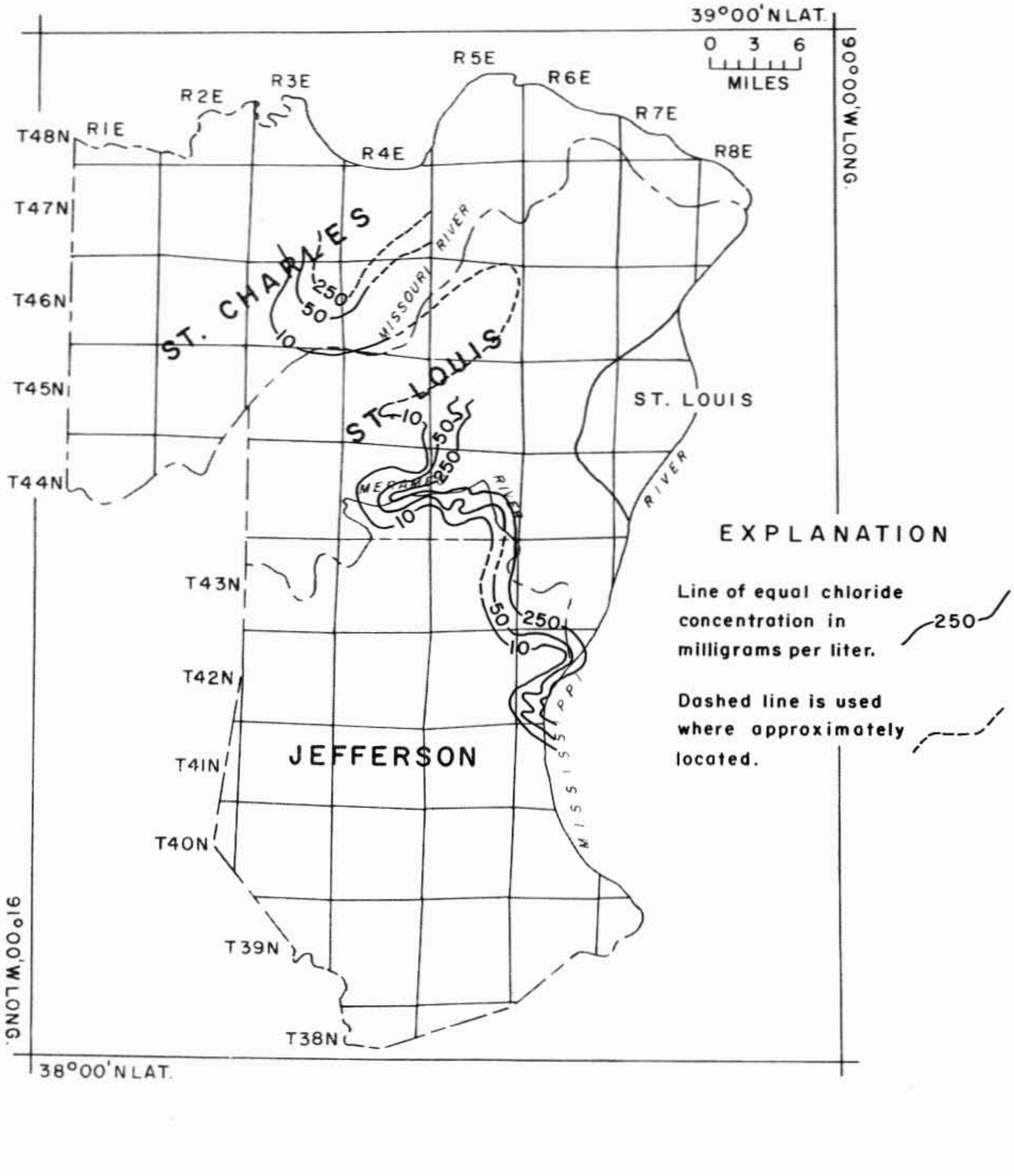



**Figure 14**

*Distribution of chloride in Group 2 (Kimmswick-Joachim) aquifers.*

Table 8

Maximum, minimum, and 25, 50, 75 percentile values for constituents in water from Group 3 (St. Peter-Everton) aquifers[a]/

[data in milligrams per liter]

| Constituent | Maximum | Percent of Samples | | | Minimum |
|---|---|---|---|---|---|
| | | 75 | 50 | 25 | |
| Silica ($SiO_2$)-------- | 13 | 9.4 | 8.4 | 6.8 | 2.0 |
| Iron (Fe)----------- | 18 | .50 | .17 | .09 | .04 |
| Calcium (Ca)--------- | 325 | 94 | 74 | 59 | 6.5 |
| Magnesium (Mg)------- | 290 | 40 | 30 | 26 | 6.3 |
| Sodium (Na)---------- | 1,810 | 35 | 15 | 7.8 | 1.6 |
| Bicarbonate plus carbonate ($HCO_3$+$CO_3$) | 536 | 380 | 347 | 314 | 217 |
| Sulfate ($SO_4$)-------- | 442 | 36 | 20 | 13 | 4.1 |
| Chloride (Cl)-------- | 5,050 | 38 | 9.0 | 3.0 | 1.4 |
| Fluoride (F)--------- | 2.5 | .7 | .4 | .3 | 0 |
| Nitrate ($NO_3$)-------- | 17 | 2.8 | .6 | .1 | 0 |
| Dissolved solids (residue at 180°C). | 7,270 | 475 | 390 | 335 | 264 |
| Hardness as $CaCO_3$---- | 1,420 | 345 | 302 | 279 | 30 |

a/ Data based on analyses from 63 wells.

generally are moderate. A comparison of the 75 percentile values of water from Group 1, 2, and 3 (tables 6, 7, and 8) shows that water from Group 3 generally is less mineralized than water from Groups 1 and 2 indicating that most of the wells bottoming in Group 3 aquifers derive their water from the St. Peter Sandstone and Everton Formation.

Most of the wells that yielded water with a high dissolved-solids content are located in or near the water-quality problem areas discussed for Groups 1 and 2. Distribution of chloride concentrations in water from Group 3 (Everton-St. Peter) aquifers is shown on figure 15. These chloride values are not as high as would be expected from connate water and they evidently are a result of leakage of more mineralized water from underlying or overlying formations.

#### GROUP 4 (POWELL-GASCONADE) AQUIFERS

Water from Group 4 aquifers generally is a moderately mineralized, calcium-magnesium-bicarbonate type in and near areas of outcrop. In eastern St. Charles, eastern St. Louis, and northeastern Jefferson Counties, where the rocks are deeply buried, the aquifers yield a highly mineralized, sodium-chloride type of water. The dissolved-solids content ranges from 256 to 9,970 mg/l. The water is generally low in iron and very hard. More than 75 percent of the wells sampled yielded water containing less than 0.3 mg/l of iron. The fluoride content of the water from Group 4 aquifers is relatively low; however, 25 percent of the samples analyzed contained more than 1.5 mg/l. Analyses of water from 48 wells are summarized in table 9. Many of these analyses are for water from Group 4 aquifers only; however, several of the wells are also open to the aquifer groups previously discussed. Selected analyses of water from Group 4 aquifers are given in appendix 2. Locations of the wells sampled are shown on plate 1 and selected analyses are shown graphically on plate 2.

Areas where Group 4 aquifers yield potable water are limited to the southern and western parts of the study area (pl. 2). Within this area, the water is predominantly a calcium-magnesium-bicarbonate type. In the vicinity of De Soto, however, water from this aquifer group has a higher dissolved-solids content and contains significant quantities of sulfate.

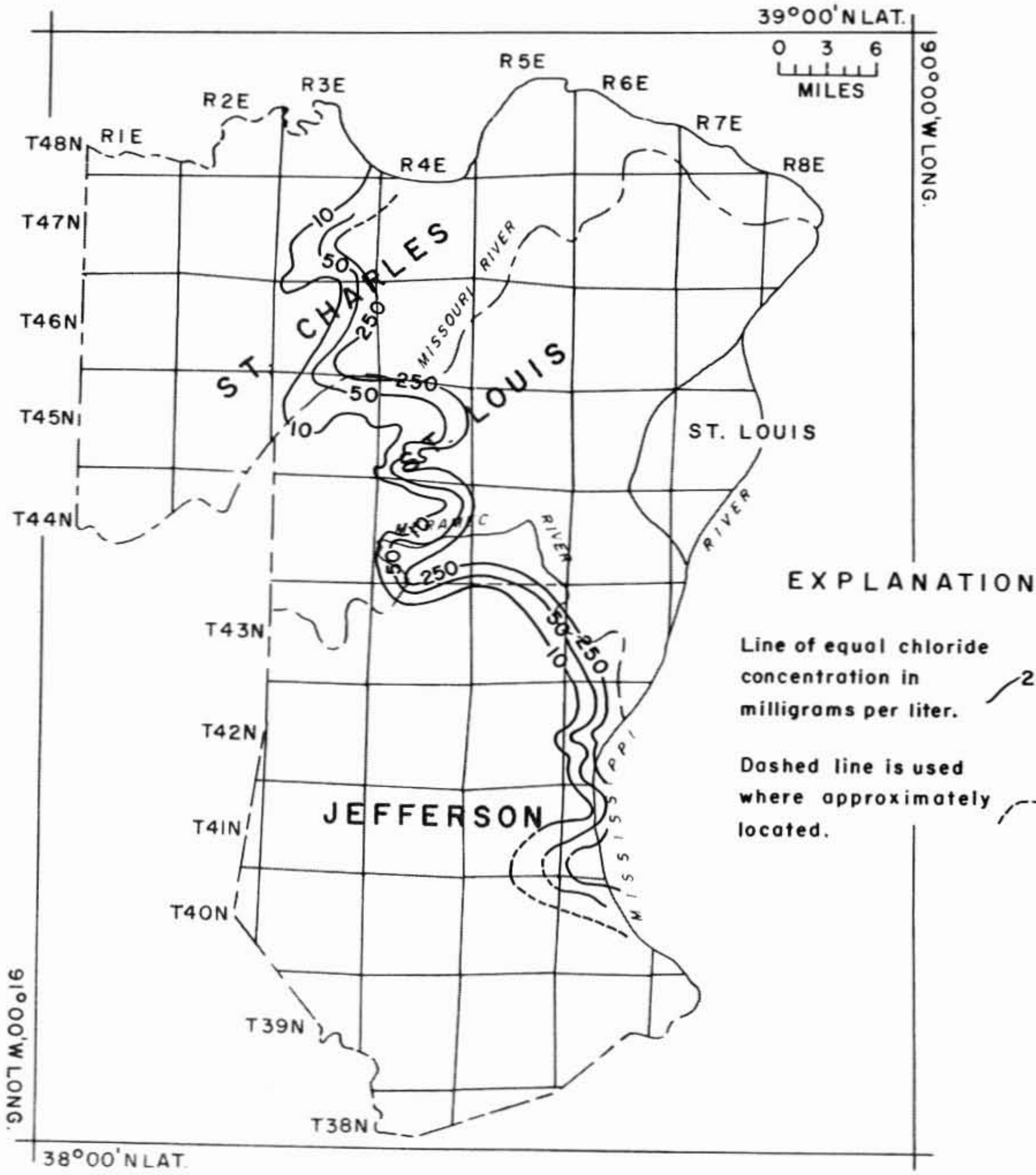



**Figure 15**

*Distribution of chloride in Group 3 (St. Peter-Everton) aquifers.*

The reason for the higher sulfate content in this area may be the oxidation and subsequent solution of sulfide minerals occurring locally.

Wells yielding water with a high chloride content are located just north of Herculaneum, adjacent to the Mississippi River in Jefferson County and in the Valley Park area in St. Louis County (fig. 16). The wells north of Herculaneum are located on the downthrown side of a fault, and it is probable that connate water has not been flushed from the aquifers here. In the Valley Park area, these aquifers contain highly mineralized water and they are presumed to be the source of mineralized water in the overlying formations. Wells in Valley Park that were drilled into these aquifers flowed at the surface. Some of these wells were abandoned. One of the wells is still flowing, indicating that the hydrostatic pressure is sufficient to move the mineralized water upward into the other formations.

#### GROUP 5 (EMINENCE-LAMOTTE) AQUIFERS

Potable water in Group 5 aquifers is limited to the southern third of the study area. Farther to the north and northeast these rocks are deeply buried and contain highly mineralized water (pl. 2). The results of chemical analyses of water from 24 wells are summarized on table 10, and selected analyses are given in appendix 2. Locations of the wells sampled are on plate 1, and selected analyses are shown graphically on plate 2. The dissolved-solids content of water from wells in Group 5 aquifers ranged from 279 to 13,500 mg/l, the lower values characteristic of water from wells near the outcrop and the higher values characteristic of water downdip.

The water is very hard and generally is low in both iron and fluoride content. Values given for the 50 and 25 percentiles on table 10 indicate the calcium-magnesium-bicarbonate character of the water at the lower dissolved-solids contents. A comparison of the 50 and 75 percentile values shows that increases in dissolved-solids content in excess of about 400 mg/l are due principally to increases in the sodium and chloride contents. Although the 50 and 25 percentile values emphasize the calcium-magnesium-bicarbonate character of the water, minor variations in the concentrations of other constituents can be expected because of the influence of water from overlying aquifers which may be open to the well.

Table 9

Maximum, minimum, and 25, 50, 75 percentile values for constituents in water from Group 4 (Powell-Gasconade) aquifers[a]

[Data in milligrams per liter]

| Constituent | Maximum | Percent of Samples 75 | 50 | 25 | Minimum |
|---|---|---|---|---|---|
| Silica ($SiO_2$)-------- | 20 | 8.9 | 7.2 | 5.6 | 2.3 |
| Iron (Fe)------------ | 4.0 | .25 | .11 | .06 | .01 |
| Calcium (Ca)--------- | 479 | 95 | 78 | 68 | 18 |
| Magnesium (Mg)------- | 201 | 51 | 39 | 32 | 22 |
| Sodium (Na)---------- | 2,570 | 40 | 15 | 7.0 | 2.5 |
| Potassium (K)-------- | 13 | 7.8 | 4.1 | 2.2 | 1.3 |
| Bicarbonate plus carbonate ($HCO_3$+$CO_3$). | 597 | 420 | 350 | 310 | 134 |
| Sulfate ($SO_4$)-------- | 564 | 71 | 37 | 21 | 3.1 |
| Chloride (Cl)-------- | 4,550 | 45 | 10 | 4.2 | 2.0 |
| Fluoride (F)--------- | 3.0 | .71 | .2 | .1 | .0 |
| Nitrate ($NO_3$)-------- | 55 | 1.5 | .4 | .1 | 0 |
| Dissolved solids (residue at 180°C). | 9,970 | 610 | 430 | 360 | 256 |
| Hardness as $CaCO_3$---- | 2,020 | 440 | 350 | 300 | 68 |

a/ Data based on analyses from 48 wells.

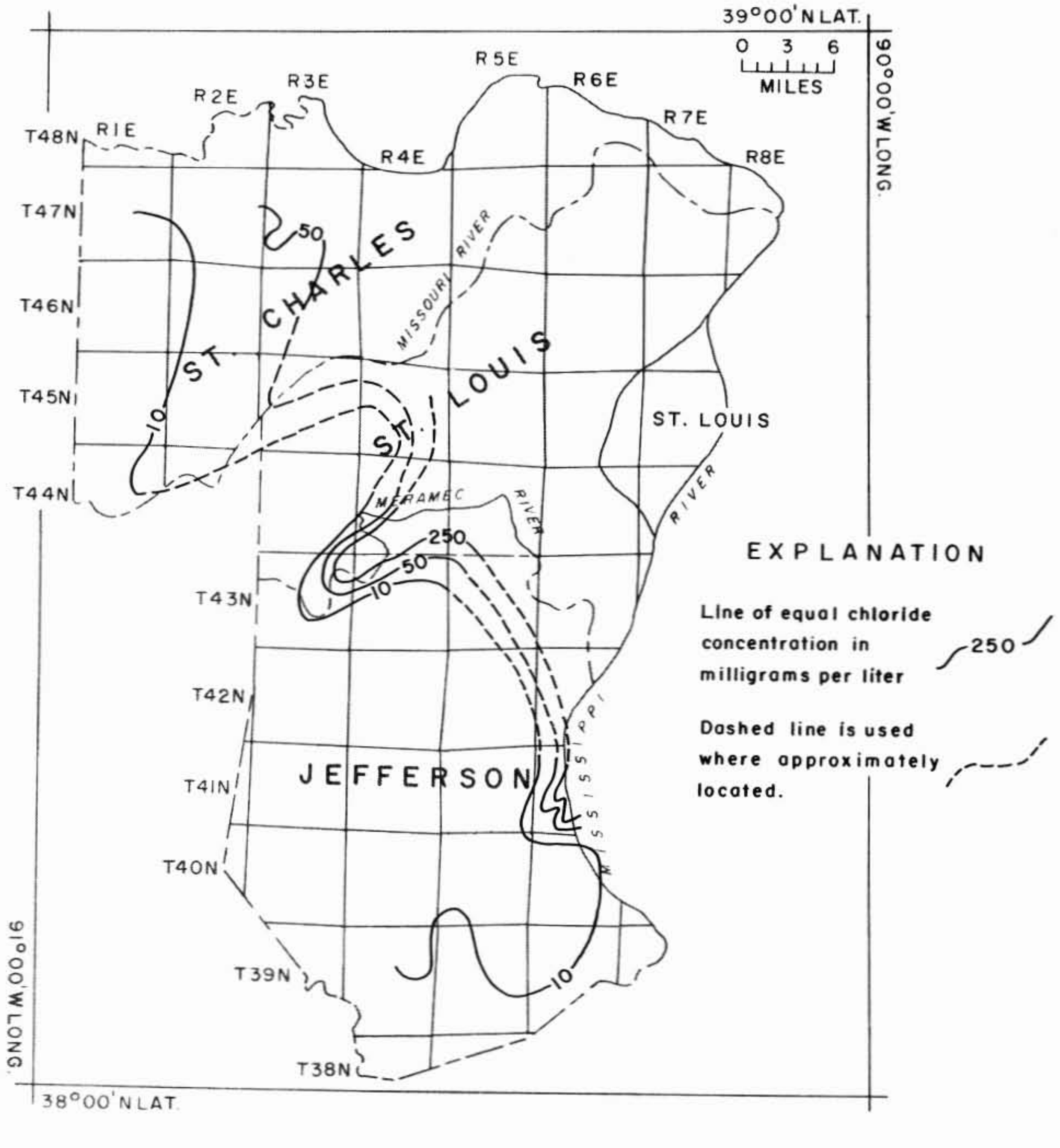



**Figure 16**

*Distribution of chloride in Group 4 (Powell-Gasconade) aquifers.*

## ALLUVIAL AQUIFERS

### MISSISSIPPI AND MISSOURI RIVER ALLUVIUM

Water from alluvial deposits along the Mississippi and Missouri Rivers has fairly uniform chemical characteristics, except that it varies widely in dissolved-solids content. The water generally is a calcium-magnesium-bicarbonate type and locally may contain significant quantities of sulfate. The iron and manganese contents commonly are high, and the water is very hard. Complete analyses are given in table 2, appendix 2. Locations of the wells are shown on plate 1 and selected analyses are shown graphically on plate 2. The maximum and minimum values and the values which were equal to or less than that found in 75, 50, and 25 percent of the samples analyzed are given in table 11. These data emphasize the calcium-magnesium-bicarbonate character of the water. A comparison of the 75 percentile values with the maximum values shows that the near-maximum values for sodium, chloride, and nitrate are unusual. The maximum value for nitrate probably is a result of contamination from a surface waste source. The maximum values for sodium and chloride are thought to result from the infiltration of saline water from a nearby flowing deep well.

Areal variations in the chemical character and dissolved-solids content of the water are indicated by the graphical representation of selected analyses in plate 2. These bar diagrams emphasize the predominant calcium-magnesium-bicarbonate character of water in most of the area. Except for wells 47-4-30b and 48-7-33d, variations in the chemical character and dissolved-solids content of the water appear to be random and are probably caused by variations in the chemical composition of the aquifer material, by the length of time the water has been in contact with the aquifer material, and by the differences in permeability of the aquifer.

### MERAMEC RIVER ALLUVIUM

Water from alluvial deposits along the Meramec River generally is a calcium-magnesium-bicarbonate type. However, in local areas, principally Valley Park and Times Beach, some wells yield a sodium-chloride type of water. For the most part the water is moderately mineralized. Dissolved-solids content

Table 10

Maximum, minimum, and 25, 50, 75 percentile values for constituents in water from Group 5 (Eminence-Lamotte) aquifers[a]

[data in milligrams per liter]

| Constituent | Maximum | Percent of Samples 75 | 50 | 100 | Minimum |
|---|---|---|---|---|---|
| Silica ($SiO_2$)-------- | 1.8 | 9.6 | 8.0 | 5.5 | 1.0 |
| Iron (Fe)------------ | 2.0 | .31 | .19 | .06 | .02 |
| Calcium (Ca)--------- | 639 | 120 | 68 | 60 | 49 |
| Magnesium (Mg)------- | 602 | 58 | 38 | 34 | 26 |
| Sodium (Na)---------- | 5,420 | 166 | 7.6 | 2.9 | 1.6 |
| Bicarbonate plus carbonate ($HCO_3+CO_3$). | 469 | 396 | 342 | 301 | 269 |
| Sulfate ($SO_4$)-------- | 547 | 48 | 23 | 18 | 13 |
| Chloride (Cl)-------- | 6,900 | 370 | 6.7 | 4.2 | 2.3 |
| Fluoride (F)--------- | 3.2 | .1 | .1 | .1 | .0 |
| Nitrate ($NO_3$)-------- | 16 | .3 | .2 | .1 | .0 |
| Dissolved solids (residue at 180°C). | 13,500 | 770 | 392 | 341 | 279 |
| Hardness as $CaCO_3$---- | 4,060 | 450 | 353 | 305 | 247 |

a/ Data based on analyses from 24 wells.

Table 11

Maximum, minimum, and 25, 50, 75 percentile values for constituents in water from Mississippi and Missouri River alluvium

[Data in milligrams per liter, or as indicated]

| Constituent | Maximum | Percent of Samples 75 | 50 | 25 | Minimum |
|---|---|---|---|---|---|
| Temperature (°C)----- | 19 | 15 | 13.5 | 13 | 12 |
| Silica ($SiO_2$)-------- | 37 | 30 | 26 | 22 | 12 |
| Iron (Fe)------------ | 48 | 9.4 | 5.2 | 2.9 | .06 |
| Manganese (Mn)------- | 4.3 | .95 | .75 | .39 | .15 |
| Calcium (Ca)--------- | 172 | 133 | 106 | 81 | 46 |
| Magnesium (Mg)------- | 48 | 34 | 26 | 19 | 10 |
| Sodium (Na)---------- | 224 | 16 | 11 | 7.6 | 1.1 |
| Potassium (K)-------- | 6.2 | 5.0 | 3.9 | 1.4 | .8 |
| Bicarbonate ($HCO_3$)--- | 784 | 528 | 449 | 332 | 184 |
| Sulfate ($SO_4$)-------- | 132 | 71 | 26 | 8.9 | .4 |
| Chloride (Cl)-------- | 334 | 7.5 | 4.1 | 2.0 | .5 |
| Fluoride (F)--------- | .5 | .4 | .2 | .2 | .0 |
| Nitrate ($NO_3$)-------- | 15 | 1.1 | .2 | .0 | .0 |
| Dissolved solids (residue at 180°C). | 1,030 | 596 | 476 | 385 | 205 |
| Hardness as $CaCO_3$)--- | 820 | 513 | 402 | 312 | 156 |
| Specific Conductance (Micromhos at 25°C). | 1,760 | 884 | 773 | 625 | 316 |
| pH (units)----------- | 8.2 | 8.0 | 7.6 | 7.3 | 7.0 |
| Color (units)-------- | 35 | 6 | 4 | 2 | 0 |

ranges from 122 to 1,070 mg/l and 75 percent of the samples contained less than 476 mg/l. Hardness of the water ranges from 88 to 456 mg/l, with most of the water being very hard. The water also contains significant quantities of iron and manganese. Sixty-six percent of the samples exceeded the U.S. Public Health Service (1962) drinking water standards of 0.3 mg/l for iron. The ranges in concentration and the 75, 50, and 25 percentiles of the principal constituents and properties of the water are given in table 12. A comparison of the maximum values with those equal to or less than that found in 75 percent of the samples indicates that near-maximum values are, for the most part, unusual. Selected analyses are given in table 2, appendix 2. Locations of the wells are shown on plate 1, and selected analyses are shown graphically on plate 2.

Areal differences in the chemical character of the water are caused by variations in the lithology and permeability of the alluvial deposits, by intrusion of saline water from bedrock formations, and locally by effluents from septic tanks or other waste-disposal systems. Water-quality characteristics vary in most parts of the alluvial area because of the variability of the character and composition of aquifer materials, principally the amount of clays and degree of sorting. In general, the dissolved-solids content is lower along the bluffs or outer edge of the alluvium and increases gradually as the water moves toward the river. The high nitrate content of water from a

Table 12

Maximum, minimum, and 25, 50, 75 percentile values for constituents in water from Meramec River alluvium

[data in milligrams per liter, or as indicated]

| Constituent | Maximum | Percent of Samples 75 | 50 | 25 | Minimum |
|---|---|---|---|---|---|
| Temperature (°C)----- | 16 | 14 | 14 | 13 | 12 |
| Silica ($SiO_2$)-------- | 20 | 12 | 11 | 9.6 | 8.8 |
| Iron (Fe)------------ | 21 | 2.2 | .75 | .17 | .00 |
| Manganese (Mn)------- | 4.6 | .85 | .76 | .28 | .00 |
| Calcium (Ca)--------- | 150 | 86 | 66 | 57 | 20 |
| Magnesium (Mg)------- | 34 | 25 | 20 | 16 | 9.0 |
| Sodium (Na)---------- | 230 | 34 | 21 | 8.4 | 4.0 |
| Potassium (K)-------- | 8.0 | 2.8 | 1.8 | 1.4 | .8 |
| Bicarbonate ($HCO_3$)--- | 478 | 266 | 212 | 158 | 100 |
| Sulfate ($SO_4$)-------- | 280 | 65 | 45 | 34 | 10 |
| Chloride (Cl)-------- | 480 | 56 | 29 | 9.2 | 2.7 |
| Fluoride (F)--------- | .3 | .1 | .0 | .0 | .0 |
| Nitrate ($NO_3$)-------- | 17 | 2.3 | .4 | .0 | .0 |
| Dissolved solids (residue at 180°C). | 1,070 | 476 | 351 | 299 | 122 |
| Hardness as $CaCO_3$---- | 456 | 324 | 247 | 212 | 88 |
| Specific conductance (Micromhos at 25°C)------------- | 1,790 | 806 | 593 | 488 | 210 |
| pH (units)----------- | 8.1 | 7.7 | 7.8 | 7.3 | 6.5 |
| Color (units)-------- | 75 | 5 | 5 | 2 | 1 |

few of the wells is presumably caused by waste-disposal practices.

Anomalous areas of higher dissolved-solids content are in the Valley Park and Times Beach areas. Available data indicate that the higher dissolved-solids content is due to the increased sodium and chloride content and that the more highly mineralized water is the result of natural upward leakage of saline water from the bedrock formations. Leakage also occurs through nonplugged abandoned wells which were drilled into the Roubidoux Formation.

The area of greatest impact of increased mineralization of water in the alluvium is in the western side of Valley Park in the vicinity of well 17 cbd and well 17 cdb. The distribution of chloride in the alluvium in Valley Park for periods of high and low water levels is shown in figure 17. The chloride content at approximately monthly intervals is shown in table 13 for the two industrial wells and the two Valley Park municipal wells (18 $dda_1$ and 18 $dda_2$).

Although the chloride content of water from these wells varies considerably with time, the patterns of chloride distribution are similar. The isochlors apparently shift slightly in response to the relative pumping rates and duration of pumping of the production wells in the area; that is, if well 17 cbd is being pumped at a greater rate than well 17 cdb, higher concentrations of chloride will be nearer well 17 cbd, but if both wells are shut down and

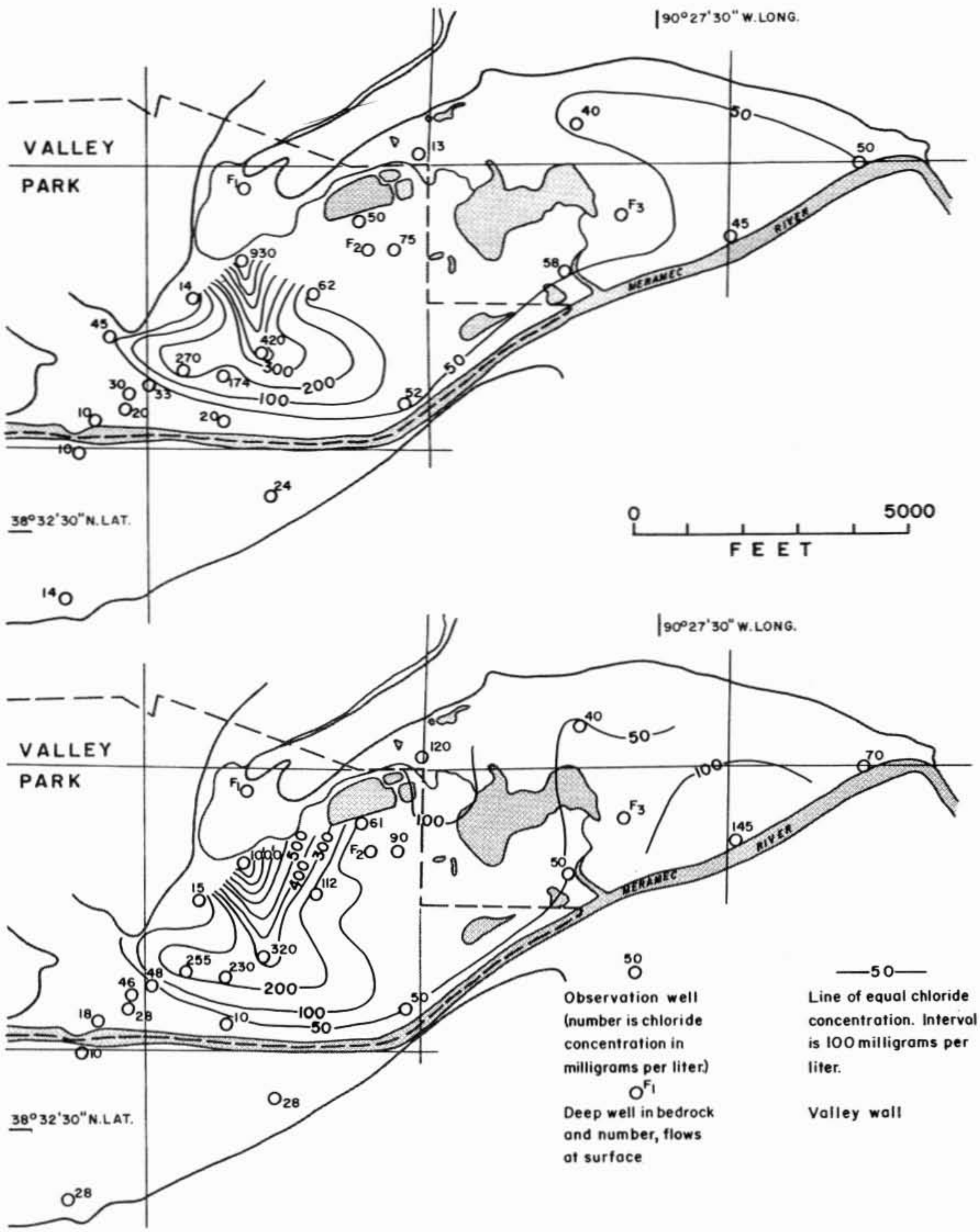



Figure 17

*Distribution of chloride in alluvial deposits in the Valley Park-Kirkwood area. In May 1970 (top), the water levels were relatively high. In July 1970 (bottom), the water levels were relatively low.*

only municipal wells $18dda_1$ and $18dda_2$ are pumping, the high chloride water will migrate toward the municipal wells.

The principal source of mineralized water is presumed to be abandoned or leaky deep wells. Well $F_1$ has been plugged and cannot be sampled, but the chemical quality of its water should be similar to that from wells $F_2$ and $F_3$. Partial analyses of water samples from these two wells are given below:

**Dissolved constituents are expressed in milligrams per liter**

| Well | Date | Calcium | Magne-sium | Sodium | Bicar-bonate | Sulfate | Chloride | Dissolved solids |
|---|---|---|---|---|---|---|---|---|
| $F_2$ | 6-4-68 | 465 | 190 | 2,380 | 257 | 280 | 4,640 | 9,210 |
| $F_3$ | 6-4-68 | 450 | 180 | 2,350 | 256 | 253 | 4,680 | 8,930 |

A graphical comparison of analyses of water from well $F_2$, wells 17 cbd and 17 cdb at Ashland Chemical Co. and Absorbent Cotton Co., and Valley Park municipal well no. 1 (fig. 18) shows the similarity of the type of water from the deep well and from wells 17 cbd and 17 cdb. The pattern for Valley Park no. 1 well does not show the effect of more mineralized water, but a tabulation of this well's chloride data (tbl. 13) does show an increase in chloride content beginning with samples collected in December 1970. This indicates that more mineralized water was moving into this well at that time.

Water in alluvial deposits in the Times Beach area, particularly in T. 44 N., has a higher dissolved-solids content and is similar in chemical character to that in the Valley Park area. The chloride content of water from selected wells in the Times Beach area is shown in table 14. These data show a considerable range in concentration of chloride; however, public supply well 44-4-32bdd is consistently high, probably because the pumping of this well draws water with a higher chloride content into the well. Areal variation in chloride content for two periods are shown in figure 19. Chloride values on these illustrations indicate that the maximum concentration of chloride shifts about midway from the bluffs to the river. However, all of the water in this area is affected by the intrusion of mineralized water. Water from well 44-4-31dca adjacent to the bluff has a higher chloride content than that in wells just south of this area. For the most part, the origin of the more mineralized water in the Times Beach area is presumed to be from an underlying bedrock formation. However, the ways in which the more mineralized water reaches the alluvium are not known.

## SPRINGS

Discharge measurements in the three-county area indicate that the springs are small and quite variable, reacting quickly to precipitation and having little or no flow during dry weather. This variability severely limits their economic significance because most enterprises utilizing springflow require a stable, dependable source. In fact, only one small commercial operation using springs (watercress production) exists in the area at this time. As reported by Lutzen of the Missouri Geological Survey (oral commun., 1971) some of the springs are affected by effluent from septic tanks, lagoons, and sanitary landfills, making them esthetically undesirable and further limiting their small economic potential.

## SURFACE WATER

A tremendous surface-water resource is one of the principal reasons for the continuing economic growth and development of this three-county area. The Mississippi, Missouri and Meramec Rivers furnish water for most of the population and industries, provide navigable waterways for commerce and recreation, and are a means for disposal of industrial wastes and sewage. The combined flow of the Mississippi and Missouri Rivers at St. Louis averages 112,000 mgd and the Meramec River near Eureka averages 1,930 mgd. Of the vast amount of available surface water, an average of only about 1,120 mgd is withdrawn for all uses.

It is quite evident that there is no shortage of surface water supplies for the major users who can tap the large rivers of the area. However, users who are interested in smaller supplies from tributary streams (those streams which originate in or have much of their drainage basin in the project area) face more difficult problems. The frequency data and interpretations presented in the remainder of this section of the report can be used as a guide toward the optimum utilization of these valuable resources. The information used for surface water computations was compiled from an extensive network of streamflow data sites, as shown in figure 2.

Table 13

Chloride content of water from selected wells in the Valley Park area, Mo.

[In milligrams per liter]

| Date | Well Number | | | |
|---|---|---|---|---|
| | 44-5-17cbd | 44-5-17cdb | 44-5-18dda | 44-5-$18dda_2$ |
| 7-22-69 | 249 | --- | 33 | 27 |
| 8-27-69 | 247 | 277 | 32 | -- |
| 9-24-69 | 245 | 265 | 30 | 25 |
| 10-24-69 | 212 | 160 | 28 | 28 |
| 11-20-69 | 248 | 200 | 25 | 25 |
| 12-18-69 | 245 | 210 | 28 | 18 |
| 1-28-70 | 262 | 208 | 32 | 24 |
| 2-27-70 | 286 | 186 | 46 | 22 |
| 3-27-70 | 322 | --- | 25 | 17 |
| 4-30-70 | 290 | 214 | 32 | 22 |
| 5-20-70 | 270 | 174 | 30 | 20 |
| 6-24-70 | 250 | 133 | 26 | 34 |
| 7-24-70 | 255 | 230 | 46 | 28 |
| 8-27-70 | 252 | 202 | 39 | 31 |
| 10-2-70 | 232 | --- | 49 | 23 |
| 12-3-70 | 152 | 302 | 65 | 33 |
| 1-29-71 | 152 | 278 | 82 | 36 |
| 3-3-71 | 162 | 242 | 75 | 30 |
| 4-5-71 | 152 | 258 | 87 | 34 |

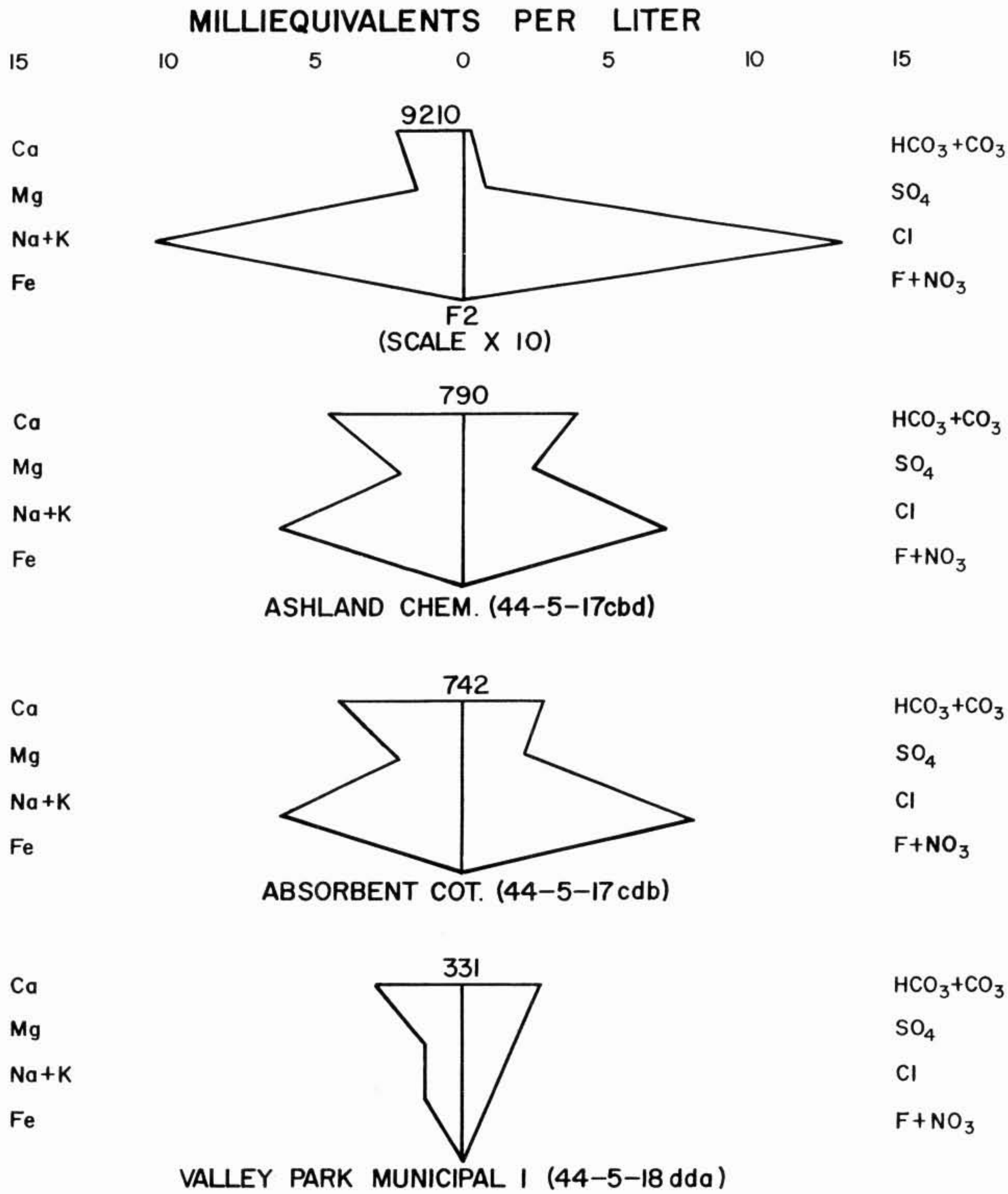



Figure 18

*Comparison of chemical analyses of water from well $F_2$, Ashland Chemical Co. well, Absorbent Cotton Co. well, and Valley Park municipal well no. 1.*

## MISSISSIPPI AND MISSOURI RIVERS

The Mississippi and Missouri Rivers are treated separately in this report because their flow characteristics are significantly different from those of other streams in the project area. They are the principal reason for the present location of the City of St. Louis and are increasingly important as national arteries of commerce. Developments having large water-supply or waste-dilution requirements naturally tend to concentrate along these great rivers.

The Missouri River is almost completely controlled by an extensive reservoir system in the headwater areas. Summer flows are maintained at levels which insure adequate depths for navigation purposes, and the flooding potential has been greatly reduced. The Mississippi River, on the other hand, is not significantly controlled at medium and high stages above the confluence with the Missouri. Navigation depths are maintained by a system of locks and dams which alter mean and high flows very little; thus, flooding is a more frequent problem on this river.

In order to fully analyze the streamflow data for the gaging stations on the two rivers, a complete systems analysis of the basins upstream from the stations would be required. This would involve the development of flow-storage models of reservoirs and channels and generation of natural-flow data for model input. These procedures are beyond the scope of this study because of their cost and complexity and must be deferred until methodology is developed. However, the available statistical and flow variability data are relevant to many current and future studies; these data are presented in appendix 3.

## DURATION OF FLOWS

The slope and shape of the flow duration curve indicate the variability of streamflow and hydrologic characteristics of a drainage basin, thus providing an excellent comparison of the flow characteristics of streams (fig. 20). A curve with steep slope denotes a

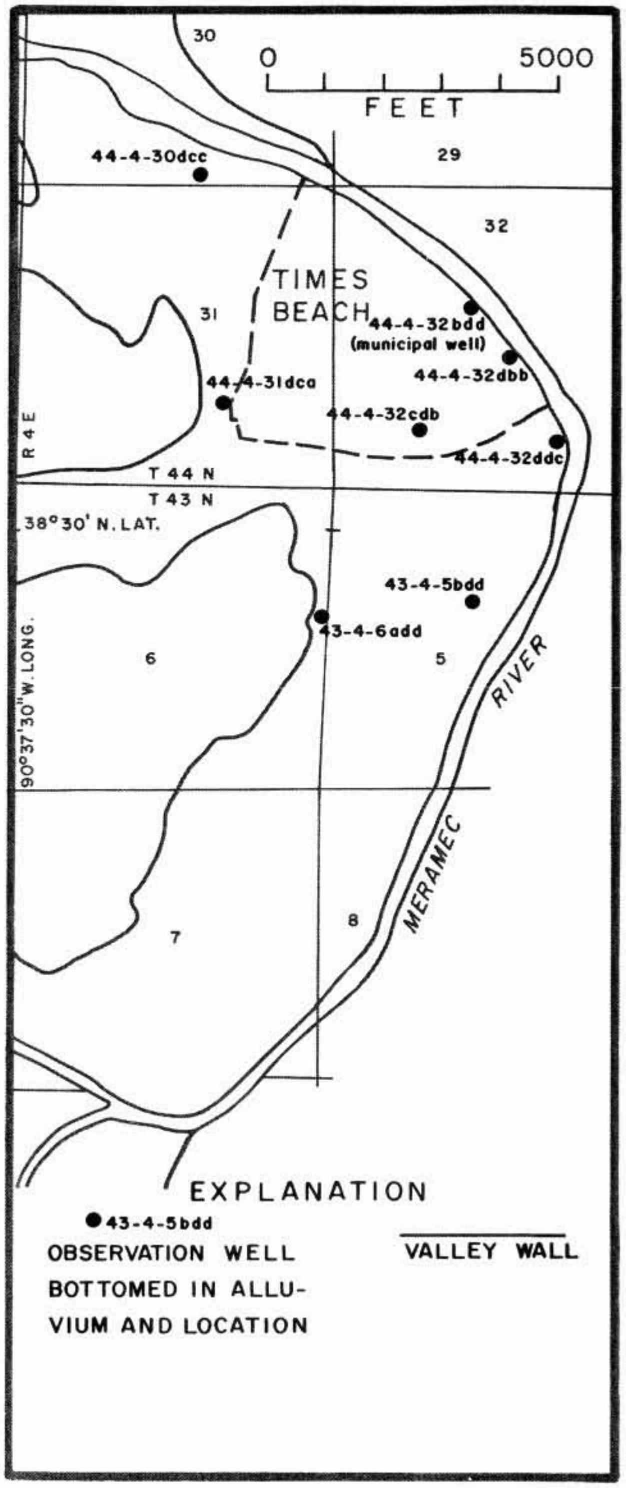



Figure 19

*Location of wells in the Times Beach area.*

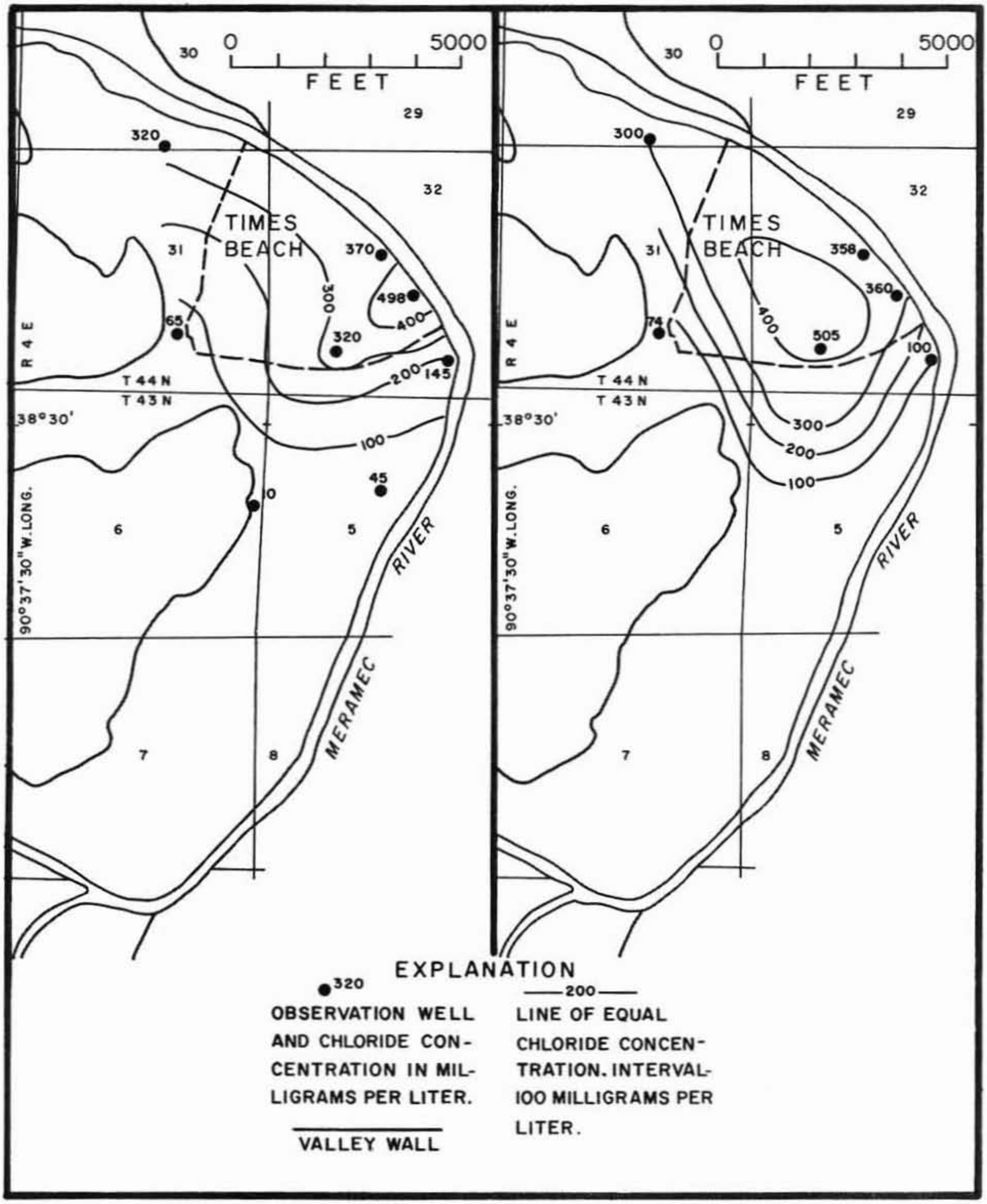



Figure 19 (continued)

*Chloride distribution in alluvial deposits in the Times Beach area, October 1969.*

*Chloride distribution in alluvial deposits in the Times Beach area, February 1970.*

Table 14

Chloride content of water from selected wells in the Times Beach area, Mo.

[In milligrams per liter]

| Date | 44-4-30dcc | 44-4-31dca | 44-4-32bdd | 44-4-32cdb | 44-4-32dbb | 44-4-32ddc |
|---|---|---|---|---|---|---|
| 7-17-69 | 335 | 71 | --- | 131 | 493 | --- |
| 8-25-69 | 310 | 72 | 413 | 130 | 590 | 323 |
| 9-24-69 | 309 | 72 | 395 | 230 | 555 | 220 |
| 10-22-69 | 320 | 65 | 370 | 320 | 498 | 145 |
| 11-19-69 | 320 | 70 | 380 | 425 | 430 | 132 |
| 12-16-69 | 295 | 70 | 355 | 465 | 408 | 115 |
| 1-29-70 | 304 | 78 | 352 | 485 | 362 | 110 |
| 2-27-70 | 300 | 74 | 358 | 505 | 360 | 100 |
| 3-27-70 | 340 | 76 | 336 | 476 | 362 | 91 |
| 4-30-70 | 345 | 66 | 344 | 298 | 324 | 83 |
| 5-19-70 | 340 | 56 | 360 | 210 | 282 | 118 |
| 6-25-70 | 310 | 70 | 370 | 172 | 300 | 148 |
| 8-28-70 | 288 | 62 | 412 | 228 | 412 | 168 |
| 10-2-70 | 308 | 58 | 388 | 153 | 418 | 102 |
| 12-1-70 | 298 | 78 | 442 | 212 | 458 | 102 |
| 2-1-71 | 278 | 72 | 418 | 412 | 468 | 112 |
| 3-4-71 | 318 | 71 | 442 | 362 | 428 | 92 |
| 4-5-71 | 312 | 61 | 428 | 232 | 448 | 105 |
| 5-3-71 | 278 | 71 | 408 | 318 | 482 | 101 |
| 6-2-71 | 288 | 61 | 412 | 268 | 458 | 97 |

basin where flow is mostly from direct runoff whereas a curve with flat slope denotes a basin with large surface or groundwater storage.

The curves of figure 20 are indicative of the two types of tributary streams found in the three-county area. The Cuivre River curve represents a highly variable stream which derives much of its flow from direct runoff. This curve is characteristic of all curves plotted for small tributary streams in St. Charles, St. Louis and northern Jefferson Counties. The Big River curve is characteristic of the large tributary streams and the small, but well-sustained streams in southern Jefferson County.

The flow-duration data presented in table 15 may be considered representative of the future distribution of flows at the gaging sites, provided there are no significant future man-made developments. In many basins in the St. Louis area, developments are already planned that will completely alter the duration data presented in this report. However, these data may be valuable as a reconnaissance tool to locate areas that are desirable for future developments.

## FLOODS

Major floods have occurred during all months in the St. Louis area, but are most common in the spring and summer. While heavy general spring rains cause most of the floods, some of the greatest floods on record have occurred in the summer (tbl. 16). This is due to intense local thunderstorms that cause flash-flood conditions on small tributary streams and consequently affect the larger streams.

A tabulation of yearly flood peaks for streams in the three-county area indicates the following flood distribution pattern:

| Size of Stream | Months when floods are most likely |
|---|---|
| Thousands of square miles (for example: Mississippi and Missouri Rivers) | April through July |
| Hundreds of square miles (for example: Big and Cuivre Rivers) | March through May |
| Less than 100 square miles (for example: Plattin Creek, Murphy Branch) | May and June |

Detailed flood data (such as flood profiles) for specific streams are not shown in this report. These data have been previously published and are available from the following sources:

1. Flood inundation maps and flood profiles are available in publications of the U.S. Corps of Engineers (1964, 1965, 1966) for the following streams in Jefferson and St. Louis Counties:

In Jefferson County – Bourne, Dry, Glaize, Heads, Joachim, Plattin, Rock, Saline, and Sandy Creeks; Big, Meramec, and Mississippi Rivers.

In western St. Louis County – Meramec River, Brush and Fox Creeks in the vicinity of Pacific.

Searcy and others (1952) also presented selected flood profiles for the Mississippi, Missouri, and Meramec Rivers.

Table 15

Flow-duration data for continuous-record stations on tributary streams

[Numbers refer to stations as shown on map, Fig. 2]

| Percentage of time during period of record | Flow, in cfs, which was exceeded for indicated percentage of time: Cuivre River near Troy (No. 1) | Big River near De Soto (No. 42) | Big River at Byrnesville (No. 50) | Meramec River near Eureka (No. 52) |
|---|---|---|---|---|
| 99.5 | 0.2 | 39 | 51 | 265 |
| 99 | .3 | 44 | 59 | 290 |
| 98 | .9 | 52 | 67 | 330 |
| 95 | 2.3 | 65 | 84 | 405 |
| 90 | 5.0 | 82 | 106 | 490 |
| 80 | 13 | 111 | 145 | 640 |
| 70 | 25 | 145 | 188 | 800 |
| 60 | 45 | 182 | 240 | 1,000 |
| 50 | 78 | 235 | 312 | 1,300 |
| 40 | 130 | 305 | 425 | 1,700 |
| 30 | 235 | 425 | 598 | 2,400 |
| 20 | 460 | 640 | 900 | 3,650 |
| 10 | 1,760 | 1,180 | 1,650 | 6,700 |
| 5 | 2,530 | 2,050 | 2,950 | 11,500 |
| 2 | 5,880 | 4,500 | 5,980 | 20,000 |
| 1 | 9,100 | 6,900 | 9,630 | 28,000 |
| 0.1 | 21,000 | 16,000 | 18,000 | 55,000 |

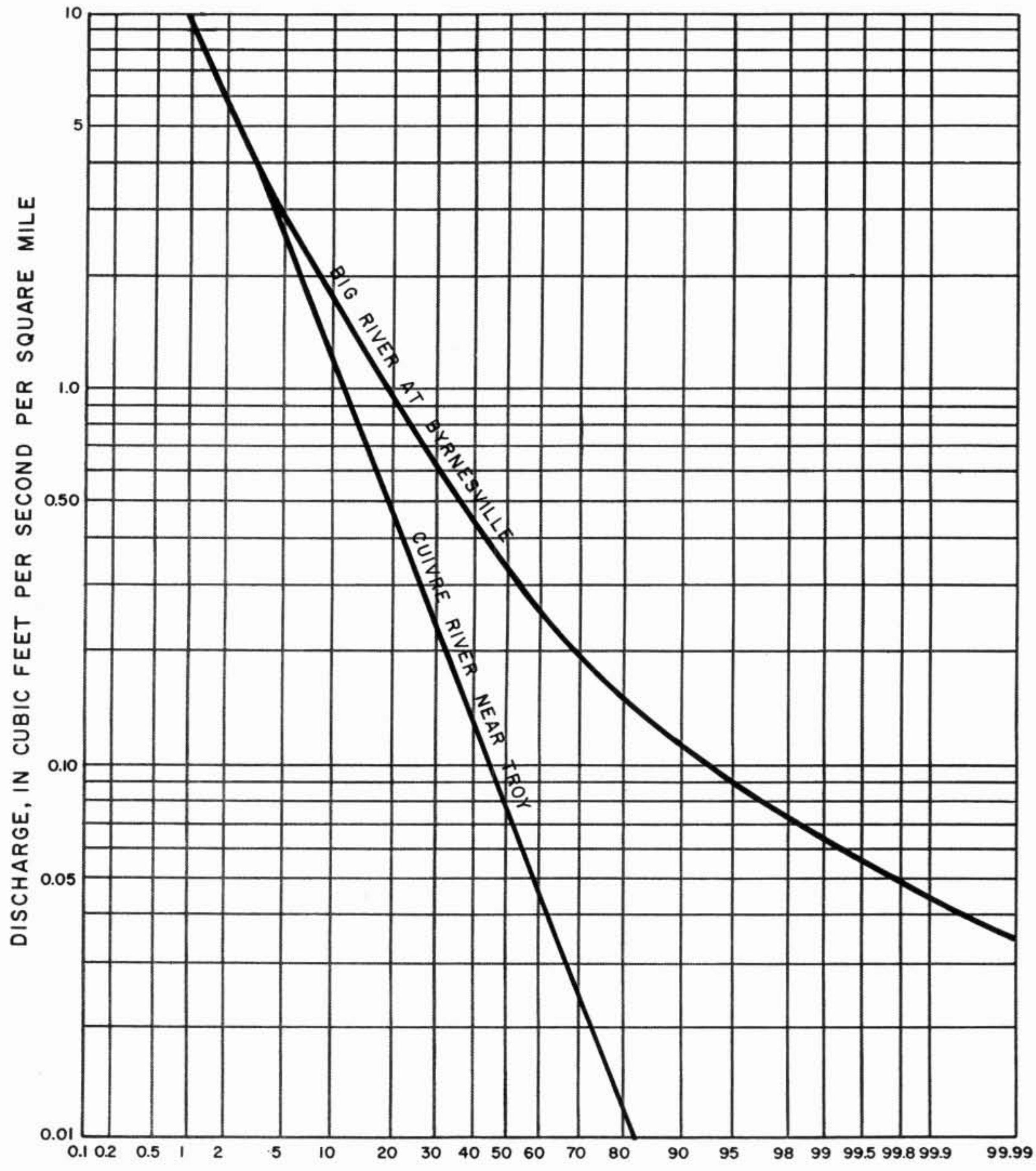



Figure 20
*Duration curves of Big and Cuivre Rivers are indicative of the differences in flow characteristics of tributary streams in the region.*

2. The outstanding Jefferson County flood of June 1964 has been documented in a report by Peterson (1965). Flood-frequency and profile data are presented for Plattin and Isle du Bois Creeks.

3. The estimated 100-year flood stages for the Mississippi and Missouri Rivers have been delineated for St. Louis and St. Charles Counties on 7½-minute topographic maps which are available from the District Chief, U.S. Geological Survey, P.O. Box 340, Rolla, Mo., 65401. Indirect flood-peak determinations on Gravois, Fox, and Sandy Creeks in St. Louis and Jefferson Counties, plus peak-stage data on a number of small Jefferson County streams, are also available from this source.

4. The U.S. Geological Survey, in cooperation with the Metropolitan St. Louis Sewer District, is conducting a study of flood characteristics in five small drainage basins in the metropolitan area. Reports on several of the basins, showing stage and inundation data are now available (Spencer and Hauth, 1968; Hauth and Spencer, 1969, 1971; Spencer, 1971).

## MAGNITUDE AND FREQUENCY OF FLOODS

The proper design and location of drainage structures and water facilities depend to some degree on information about the magnitude and frequency of flooding. These data are also important in flood-plain zoning and other related activities. In the St. Louis area, flood problems will probably become more severe on the tributary streams as industrial and domestic development on the floodplains becomes more intense.

The basic tool used in the analysis of floods for this report is the gaging-station flood-frequency

Table 16

Summary of maximum recorded floods and stages

| Map No. (Fig. 2) | Station name | Drainage area (sq mi) | Date of maximum discharge | Maximum gage height1/ (ft above mean sea level) | Discharge (cfs) |
|---|---|---|---|---|---|
| 1 | Cuivre River near Troy | 903 | Oct. 5, 1941 | 483.7 | 120,000 |
| 18 | Mississippi River at Alton | 171,500 | Apr. 29, 1973 | 432.1 | 535,000 |
| [Outside study area] | Missouri River at Hermann2/ | 528,200 | Jun. 1844 | 517.0 | 892,000 |
| 34 | Mississippi River at St. Louis | 701,000 | Jun. 27,1844 | 423.17 | 1,300,000 |
| 42 | Big River near De Soto | 718 | Aug. 1915 | 568.2 | 70,500 |
| 50 | Big River at Byrnesville | 917 | Aug. 1915 | 463.9 | 80,000 |
| 52 | Meramec River near Eureka | 3,788 | Aug. 22, 1915 | 446.4 | 175,000 |
| 77 | Plattin Creek near Crystal City | 83.4 | Jun. 17, 1964 | 3/24.06 | 30,100 |
| 80 | Isle du Bois Creek near Ste. Genevieve | 16.4 | Jun. 17, 1964 | 3/31.08 | 28,400 |

1/ Did not necessarily occur at same time as maximum discharge.

2/ Inflow between Hermann and the mouth of the Missouri River is insignificant.

3/ Arbitrary datum.

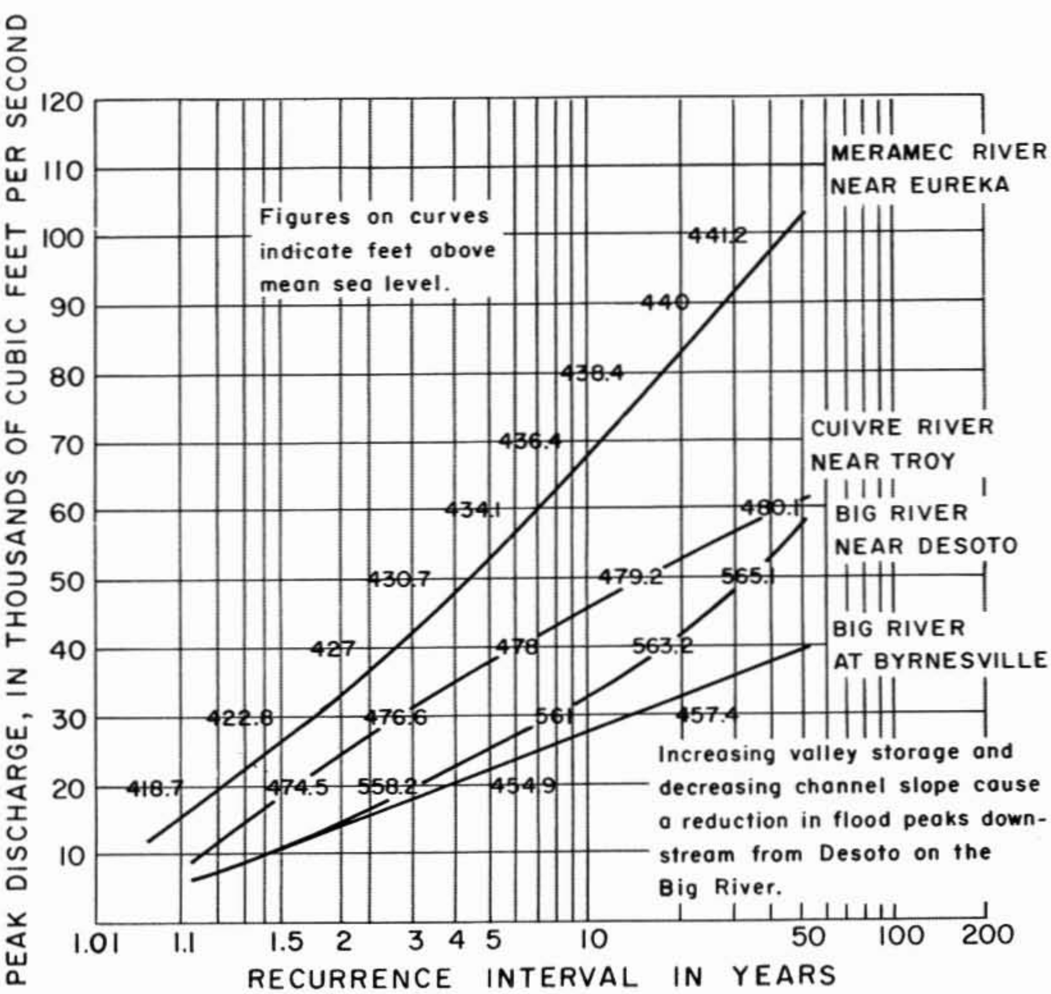



Figure 21

*Flood-frequency curves for tributary streams in the St. Louis area.*

curve. Examples of these curves for some of the large tributary streams in the St. Louis area are shown in figure 21. Flood-peak discharges at selected recurrence intervals from the station flood-frequency curves are shown in table 17 for selected stations. All flood-frequency curves were prepared using methods described by the U.S. Water Resources Council (1967).

Skelton and Homyk (1970) presented flood-frequency equations applicable to ungaged rural basins in each of Missouri's physiographic regions. Data used in computation of the equations are derived from the gaging-station frequency curves and represent an average of the flood experiences for different-size drainage areas in the region.

An analysis of residual errors (actual values divided by computed values) was made to determine the usefulness of the equations in the St. Louis area. Residuals were computed and plotted on maps to determine if any geographic patterns existed in the

Table 17

Flood-frequency data at selected continuous and partial-record stations

| Map No. (Figure 2) | Station name | Record used in analysis | Drainage area (sq mi) | Flood frequency: Magnitude of flood, in cfs, for indicated recurrence interval, in years: 2 | 5 | 10 | 25 | 50 |
|---|---|---|---|---|---|---|---|---|
| 1 | Cuivre River near Troy | 1924-69 | 903 | 23,700 | 38,300 | 46,900 | 56,200 | 62,100 |
| 18 | Mississippi River at Alton1/ | 1927-69 | 171,500 | 245,000 | 320,000 | 375,000 | 445,000 | 495,000 |
| -- | Missouri River at Hermann1/ | 1929-69 | 528,200 | 250,000 | 390,000 | 490,000 | 620,000 | 720,000 |
| 32 | Coldwater Creek near St. Louis2/ | 1960-61, 1963-65, 1968-69 | 43.6 | 3,100 | 4,600 | 6,000 | 8,200 | ------- |
| 34 | Mississippi River at St. Louis1/ | 1928-69 | 701,000 | 480,000 | 700,000 | 800,000 | 895,000 | 940,000 |
| 42 | Big River near De Soto | 1950-69 | 718 | 15,500 | 24,900 | 33,100 | 45,800 | 57,400 |
| 50 | Big River at Byrnesville | 1923-69 | 917 | 14,600 | 22,400 | 27,800 | 34,900 | 40,400 |
| 52 | Meramec River near Eureka | 1922-69 | 3,788 | 34,000 | 55,000 | 69,600 | 88,700 | 103,000 |
| 78 | Murphy Branch near Crystal City | 1955-68 | 0.44 | 135 | 280 | 430 | 720 | ------- |

1/ See Appendix 3 for low-flow, flood-volume, and flow-duration data.

2/ Stream is significantly affected by urbanization.

study area. The resulting plots showed a random distribution pattern, and the equations are thus considered valid in the St. Louis area.

The grouping of the equations according to size of upstream drainage area and physiographic region was found to be the most meaningful method of presenting the data for two reasons: (a) the considerable variation in risks among regions and drainage-area sizes (as shown by the standard error of estimate) can be better defined and, (b) the effective independent variables remaining in the final regression equations are indicative of basin characteristics most significant in each region for each drainage-area class.

There are two limitations that must be considered before using the equations. First, appropriate adjustments to the equations must be made to account for increased storm runoff during and after urbanization (see the following section, "Effects of Urbanization on Storm Runoff" for a discussion of these adjustments). Secondly, the equations are based on data from rural Missouri streams and thus do not apply to the Mississippi and Missouri Rivers.

Tables 18 and 19 present the flood-frequency equations which are applicable to rural basins in the Dissected Till Plains and Ozarks portions of the study area (fig. 1). In the case of streams that cross the Ozarks-Plains boundary, a weighted average (based on drainage area) of results from both Plains and Ozarks equations should be used.

Drainage basin characteristics are defined for the equations as follows:

1. Drainage area, A, in square miles, was determined from most recent U.S. Geological Survey topographic maps.

2. Main-channel slope, S, in feet per mile, was determined from altitudes at points 10 percent and 85 percent of the distance along the channel from the gaging station to the divide. This index was described and used by Benson (1962, 1964).

3. Mean basin altitude, E, in feet above mean sea level, was measured on 1:62,500 – and 1:24,000-scale U.S. Geological Survey topographic maps for small drainage basins and on 1:250,000-scale Army Map Service maps for large basins. The altitude was computed by laying a grid over the map, determining the altitude at each grid intersection, and averaging these altitudes. The grid spacing was selected to give at least 20 intersections within the basin boundary.

4. The maximum 24-hour rainfall, $I_{24,2}$, in inches, having a recurrence interval of 2 years (2-year 24-hour rainfall) was determined for each basin from

Table 18

Flood-frequency equations applicable to rural Dissected Till Plains basins

Model is $Y=aA^{b1}S^{b2}(E\times10^{-3})^{b3}I_{24,2}{}^{b4}S_i{}^{b5}R^{b6}$

| | | Exponents of basin characteristics | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ | $b_6$ | |
| Flow characteristic, Y | Regression constant, a | Drainage area, A (sq mi) | Main-channel slope, S (ft per mi) | Mean basin altitude E ($ft\times10^{-3}$) | 2-year, 24-hour rainfall, $I_{24,2}$ (inches)1/ | Soils index, $S_i$ (inches) | Mean annual runoff, R (inches) | Standard error of estimate (percent) |
| 2-year peak2/ | 728 | 0.64 | ---- | ---- | ---- | -0.93 | ---- | 38 |
| 2-year peak3/ | 24.6 | 0.80 | 0.61 | ---- | ---- | ---- | ---- | 28 |
| 5-year peak2/ | 1,540 | 0.64 | ---- | 1.29 | ---- | -0.85 | ---- | 33 |
| 5-year peak3/ | 0.20 | 0.83 | 0.87 | ---- | 4.69 | -1.03 | ---- | 29 |
| 10-year peak2/ | 1,890 | 0.65 | ---- | 1.52 | ---- | -0.74 | ---- | 35 |
| 10-year peak3/ | 0.19 | 0.81 | 0.83 | ---- | 5.09 | -1.07 | ---- | 34 |
| 25-year peak2/ | 1,220 | 0.66 | ---- | 1.34 | ---- | ---- | ---- | 40 |
| 25-year peak3/ | 0.20 | 0.76 | 0.73 | ---- | 5.62 | -1.13 | ---- | 41 |
| 50-year peak2/ | 35 | 1.00 | 0.95 | 2.68 | ---- | ---- | ---- | 43 |
| 50-year peak3/ | 1.23 | 0.75 | 0.77 | ---- | ---- | ---- | 2.06 | 41 |

Table 19

Flood-frequency equations applicable to rural Ozark Plateaus basins

Model is $Y=aA^{b1}S^{b2}I_{24,2}{}^{b3}R^{b4}$

| | | Exponents of basin characteristics | | | | |
|---|---|---|---|---|---|---|
| | | $b_1$ | $b_2$ | $b_3$ | $b_4$ | |
| Flow Characteristic, Y | Regression constant, a | Drainage area, A (sq mi) | Main-channel slope, S (ft per mi) | 2-year 24-hour rainfall, $I_{24,2}$ (inches)1/ | Mean annual runoff, R (inches) | Standard error of estimate (percent) |
| 2-year peak2/ | $280\times10^4$ | 0.71 | ---- | -7.16 | ---- | 57 |
| 2-year peak3/ | 223 | 0.64 | ---- | ---- | ---- | 29 |
| 5-year peak2/ | $587\times10^3$ | 0.70 | ---- | -5.48 | ---- | 50 |
| 5-year peak3/ | 405 | 0.63 | ---- | ---- | ---- | 26 |
| 10-year peak2/ | $288\times10^3$ | 0.71 | ---- | -4.69 | ---- | 50 |
| 10-year peak3/ | 585 | 0.62 | ---- | ---- | ---- | 28 |
| 25-year peak2/ | $916\times10^2$ | 0.80 | 0.27 | -4.44 | ---- | 50 |
| 25-year peak3/ | 840 | 0.61 | ---- | ---- | ---- | 31 |
| 50-year peak2/ | 935 | 0.80 | ---- | ---- | ---- | 59 |
| 50-year peak3/ | 631 | 0.48 | ---- | ---- | 0.52 | 29 |

1/ For the St. Louis area, use a value of 3.5 for $I_{24,2}$.

2/ Use this equation for drainage areas of 50 square miles or less.

3/ Use this equation for drainage areas greater than 50 square miles.

U.S. Weather Bureau Technical Paper 40 (1961). A value of 3.5 inches can be used throughout the study area.

5. Soil infiltration index, $S_i$, in inches, was determined for subbasins within the state by the Soil Conservation Service (written commun. 1970).

Weighted averages of these values were used for each gaged drainage basin. Figure 23 shows the values for the St. Louis area.

6. Mean annual runoff, R, in inches, was determined from long-term gaging-station records in eastern Missouri. Figure 24 illustrates the variation in natural runoff for tributary streams in the St. Louis area.

## EFFECTS OF URBANIZATION ON STORM RUNOFF

For the three-county study area, definitive ratios showing the effects of urbanization on storm runoff will be available within three years as a result of current urban-hydrology studies in cooperation with the St. Louis Metropolitan Sewer District and St. Louis County. Presently, however, there are

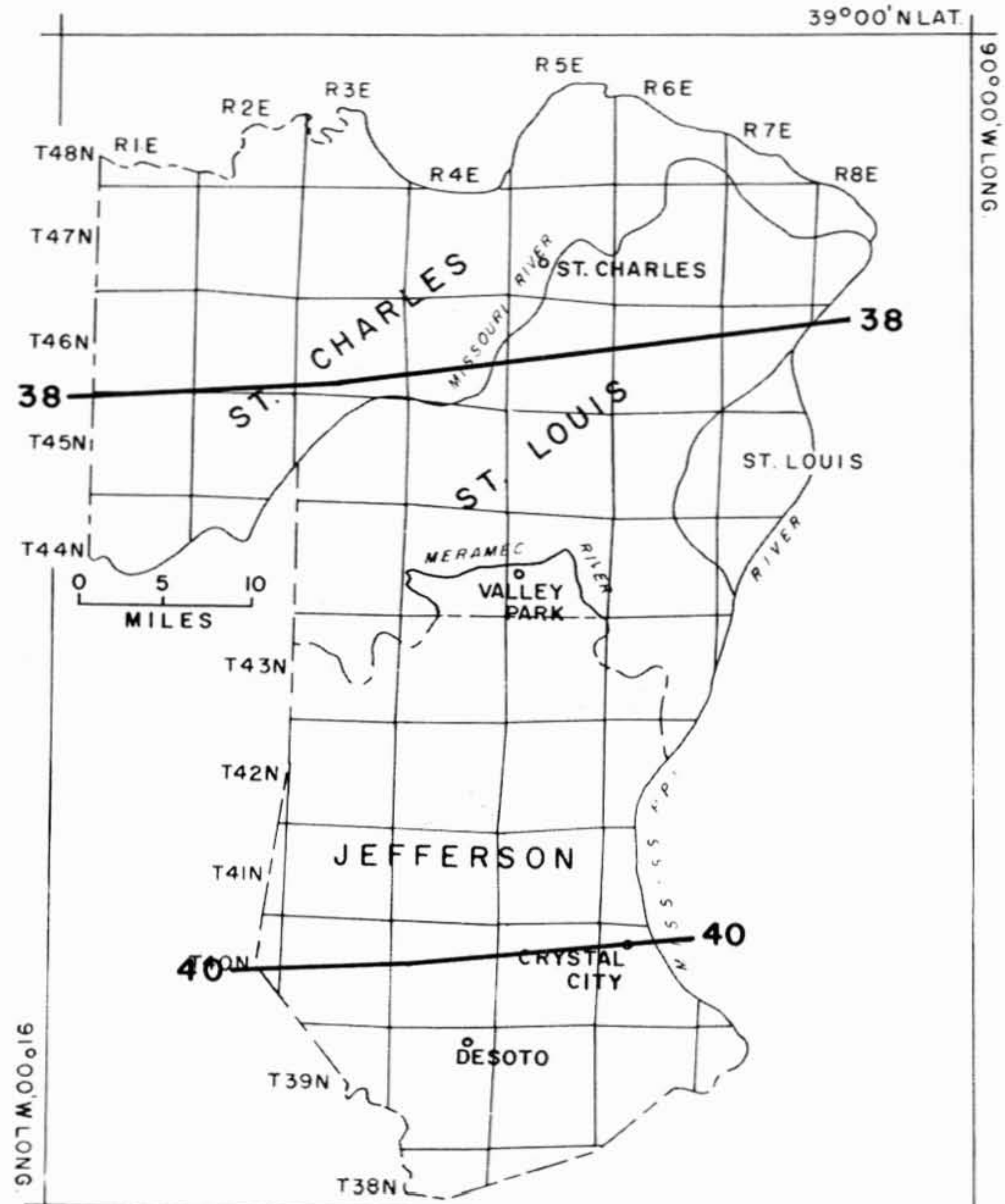



Figure 22

*Average annual precipitation, in inches, for the St. Louis area. Isohyets are based on 1931-60 data from the National Weather Service – NOAA.*

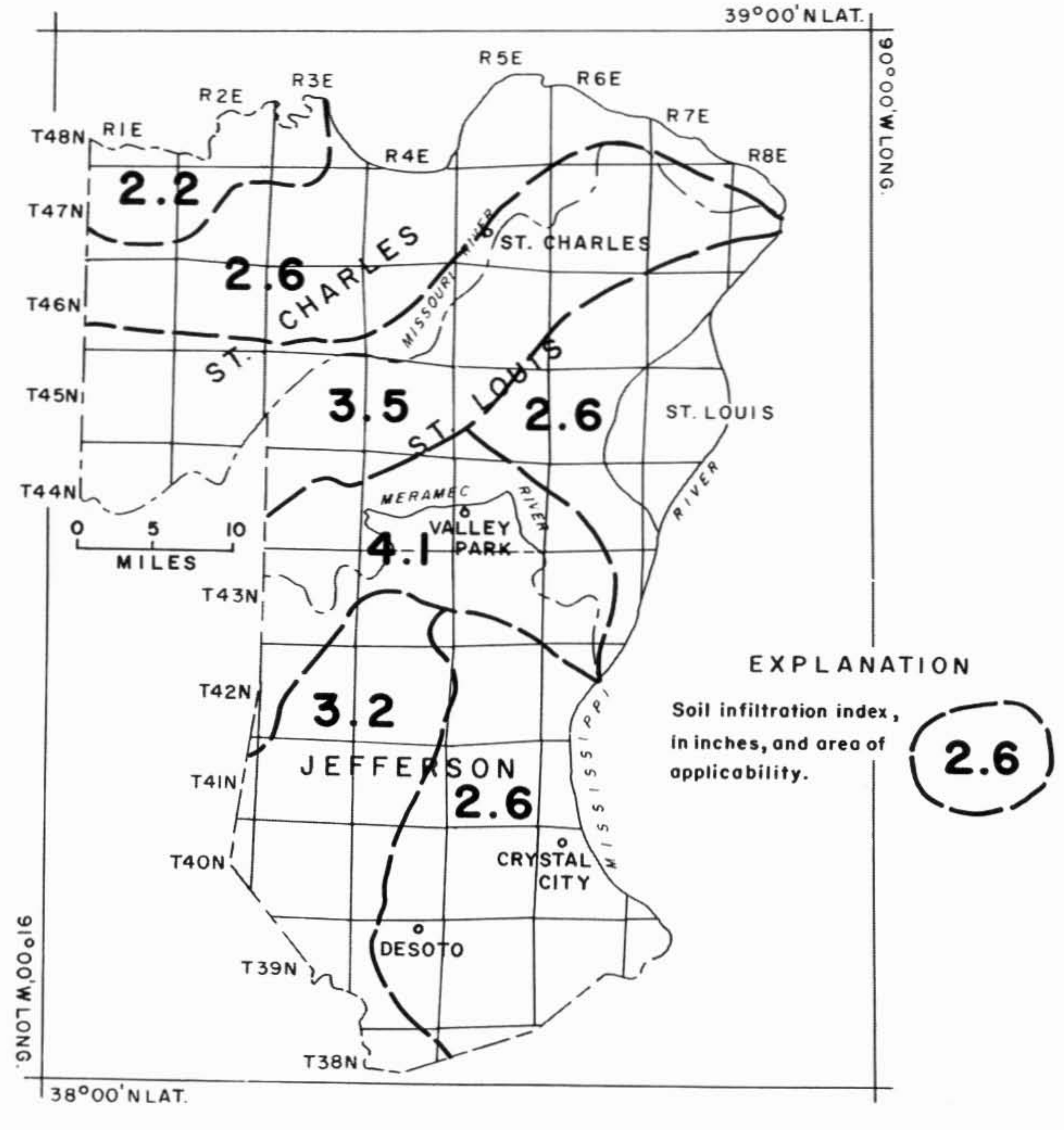



Figure 23

*Soil infiltration index values, in inches, for the St. Louis area. Data furnished by the Soil Conservation Service.*

inadequate hydrologic data to make precise evaluations of the effects of increasing urbanization on storm runoff.

For a generalized method of estimating increases in flood-peak discharge due to varying degrees of urbanization in the study area, the reader is referred to Gann (1971). The methodology presented in that report will be useful to the design engineer until more comprehensive and refined data are available.

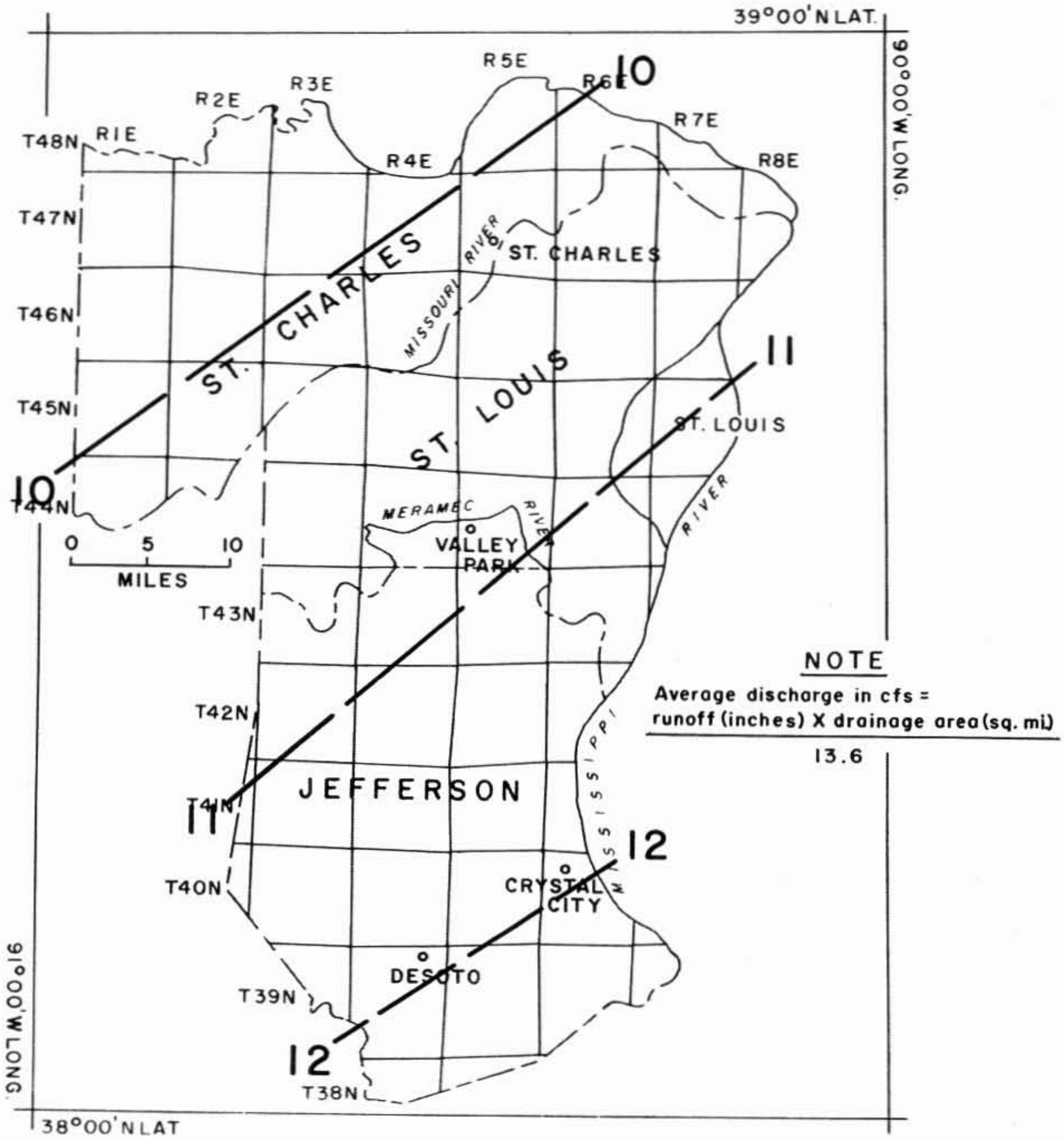



Figure 24

*Mean natural annual runoff, in inches, for tributary streams in the St. Louis area.*

## MEAN FLOWS

The variation in mean annual runoff in the study area is shown in figure 24. The illustration is based on the results of previous runoff studies of unregulated rural basins, plus an anlaysis of long-term gaging-station records in the vicinity of St. Louis.

The estimation of natural mean flow for ungaged sites in the area can be made by using figure 24. The accuracy of these estimates will be sufficient for solution of the usual hydrologic problems involving mean flows; the most common of these problems is the use of the data as a parameter in the computation of reservoir storage requirements (see subsequent section entitled "Augmentation of Dependable Flows by Storage").

### EFFECTS OF URBANIZATION ON MEAN FLOWS

In most studies in the United States, it has been observed that total runoff (amount of precipitation that appears as streamflow) is increased by urbanization. In Austin, Tex., annual runoff was increased 2.9 times in a watershed by a 21-percent-impervious cover (Espey and others, 1966). James (1965)

Table 20

Low-flow frequency data at continuous and partial-record stations

| Map no. (Fig. 2) | Station name | Record used in analysis | Drainage area (sq mi) | Low-flow frequency: Period (days) | Annual low flow, in cfs, for indicated recurrence interval, in years: 2 | 5 | 10 | 20 | 50 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Cuivre River near Troy | 1924-69 | 903 | 7 | 4.5 | 1.0 | 0.3 | 0.1 | 0 |
| | | | | 14 | 5.5 | 1.2 | 0.4 | 0.1 | 0 |
| | | | | 30 | 9.3 | 1.8 | 0.6 | 0.2 | 0.1 |
| | | | | 60 | 19 | 3.7 | 1.5 | 0.7 | 0.3 |
| | | | | 90 | 31 | 7.0 | 3.2 | 1.7 | 0.7 |
| 2 | Big Creek near Moscow Mills | 1962-64, 1967 | ---- | 7 | 0.2 | ---- | 0 | ---- | ---- |
| 7 | Peruque Creek near Wentzville | 1942-43, 1945-46 1948, 1953, 1962-63, 1967 | ---- | 7 | 0.1 | ---- | 0 | ---- | ---- |
| 14 | Dardenne Creek near Weldon Spring | 1942-43, 1945-46, 1948, 1953, 1961-63, 1967 | ---- | 7 | 0.1 | ---- | 0 | ---- | ---- |
| 22 | Femme Osage Creek near Weldon Spring | 1961-63, 1967 | ---- | 7 | 0.2 | ---- | 0 | ---- | ---- |
| 28 | Creve Coeur Creek at Creve Coeur | 1961-64, 1967 | ---- | 7 | 0.3 | ---- | 0 | ---- | ---- |
| 31 | Coldwater Creek at Shoveltown1/ | 1961-65 | ---- | 7 | 10 | ---- | 5 | ---- | ---- |
| 35 | Gravois Creek near Kirkwood1/ | 1961-65, 1967, 1969 | ---- | 7 | 0.2 | ---- | 0 | ---- | ---- |
| 42 | Big River near De Soto | 1950-69 | 718 | 7 | 88 | 50 | 35 | 27 | ---- |
| | | | | 14 | 100 | 58 | 42 | 30 | ---- |
| | | | | 30 | 115 | 68 | 48 | 35 | ---- |
| | | | | 60 | 125 | 76 | 55 | 41 | ---- |
| | | | | 90 | 155 | 95 | 70 | 52 | ---- |
| 43 | Big River near Richwoods | 1942-43, 1946-47, 1951, 1961-65, 1969 | ---- | 7 | 89 | ---- | 44 | ---- | ---- |
| 50 | Big River at Byrnesville | 1923-69 | 917 | 7 | 96 | 62 | 50 | 41 | 32 |
| | | | | 14 | 110 | 68 | 53 | 44 | 34 |
| | | | | 30 | 120 | 80 | 64 | 50 | 37 |
| | | | | 60 | 140 | 95 | 74 | 58 | 44 |
| | | | | 90 | 170 | 110 | 88 | 70 | 50 |
| 52 | Meramec River near Eureka | 1922-69 | 3,788 | 7 | 420 | 310 | 280 | 230 | 190 |
| | | | | 14 | 450 | 330 | 300 | 250 | 215 |
| | | | | 30 | 500 | 360 | 320 | 290 | 230 |
| | | | | 60 | 590 | 405 | 350 | 340 | 260 |
| | | | | 90 | 680 | 480 | 410 | 380 | 290 |
| 67 | Joachim Creek at Hematite | 1961-65, 1967-69 | 95.0 | 7 | 2.5 | ---- | 0.8 | ---- | ---- |
| 73 | Sandy Creek near Pevely | 1966-68 | 32.5 | 7 | 0 | ---- | 0 | ---- | ---- |
| 76 | Plattin Creek at Plattin | 1966-69 | 65.8 | 7 | 2.6 | ---- | 0.3 | ---- | ---- |

1/ Stream is significantly affected by urbanization. Natural low flows augmented by outflow from sewage disposal plants and lagoons. Low-flow estimates cannot be regarded as probability data, but are useful for comparative purposes.

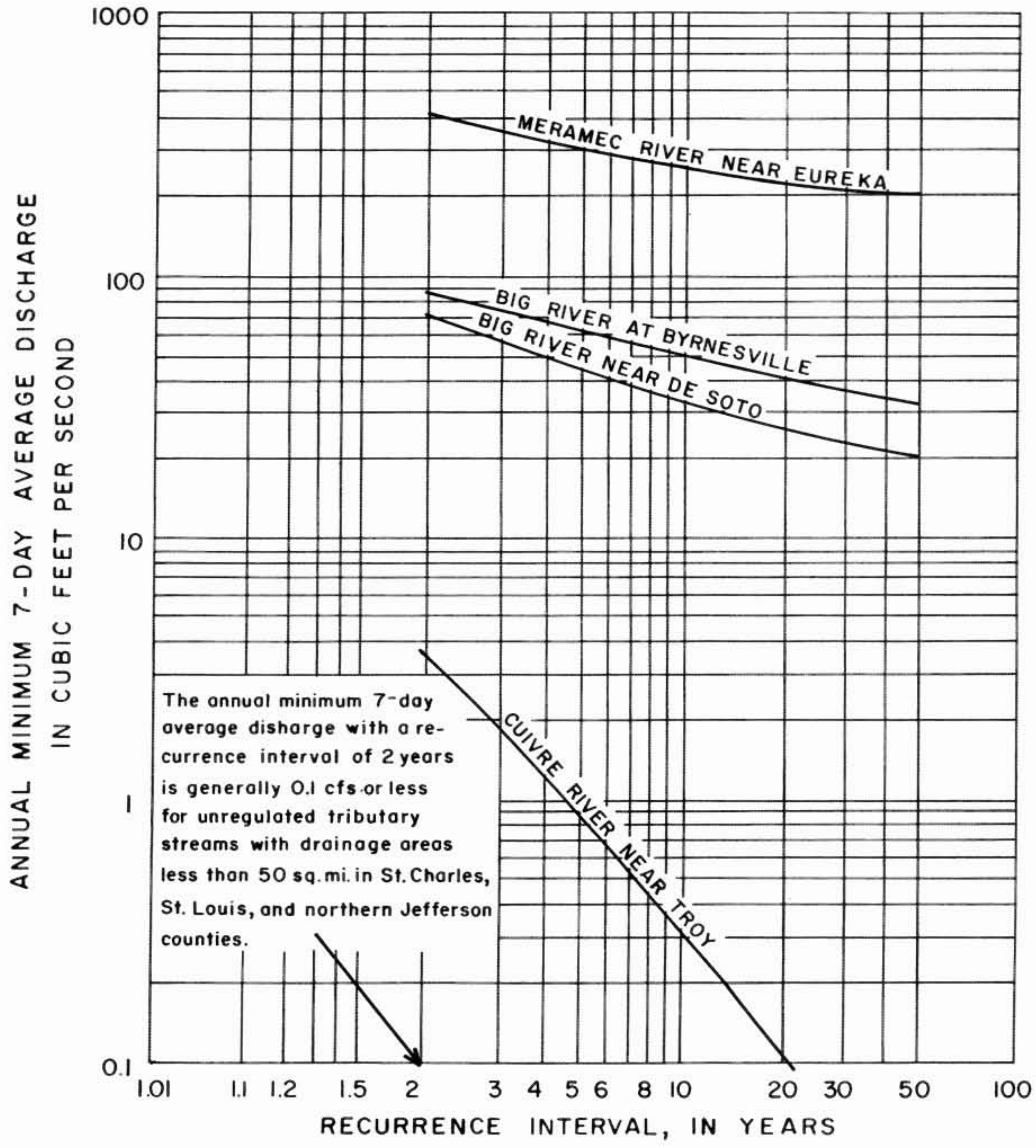



Figure 25

*Low-flow frequency curves for tributary streams in the St. Louis area.*

estimated that the annual runoff from a completely urbanized California stream basin was 2.3 times its natural volume. Crippen and Waananen (1969) showed that, during years of normal precipitation, the increase in annual runoff from partial urbanization of a small California basin was about threefold. These results are logical because one of the primary controls on runoff is the basin infiltration characteristics, and these are directly related to the percentage of impervious area in a basin.

Streamflow records on Coldwater Creek (about 60-percent urbanized with an estimated 20 percent of the urbanized area impervious) represent the only runoff data of any consequence collected on an urbanized basin in the St. Louis area. These data, when adjusted for record length on the basis of nearby long-time streamflow records, indicate that the average annual runoff from the basin is about 22 inches. This is approximately twice the average for rural basins in the area (see fig. 24). A part of this increase is due to the operation of sewage treatment plants in the basin. Crippen and Waananen (1969) stated that *"Development . . . has produced a marked increase in the total runoff. Such an increase has been noted in other studies, and is probably more pronounced in the semi-arid California climate than in more humid regions."*

Based on the studies in California and Texas, plus the data from Coldwater Creek, it is recommended that the mean flow of streams in the study area, with urban development similar to that of Coldwater Creek, be adjusted for urbanization effects by multiplying the natural runoff chosen from figure 24 by 1.5. If treatment plants are present in the basin, the mean flow could be twice as high as that shown on figure 24. Until more comprehensive urban runoff data are available, recommendations cannot be made for adjusting data from basins with varying degrees of urbanization.

## LOW FLOWS

The utilization or development of a stream depends, to some extent, on its low-flow characteristics as defined by low-flow frequency data (table 20). These data are the principal tool used by hydrologists and planners to evaluate the low-flow potential of streams.

For this report, low-flow frequency data were computed by statistical methods described by Skelton (1966). Examples of low-flow frequency curves (fig. 25) are presented to indicate the variations in low-flow characteristics of some major tributary streams in the region. The Meramec and Big River curves represent streams with high, well-sustained base flows, while the Cuivre River curve indicates that this stream has a highly variable low flow that can diminish rapidly during a severe drought.

Data from low-flow partial-record stations and continuous-record stations with less than five annual minima are inadequate to define a low-flow frequency curve. These data were related to long-term gaging-station data in the area, and the resulting graphical regression was used to estimate the median annual minimum 7-day flows (7-day $Q_2$) and the 7-day 10-year-recurrence-interval flows shown in table 20.

Estimates of low-flow characteristics at ungaged sites in the area can be made by using a method described by Skelton (1970). Briefly, the method involves measuring low flow at the site on different recessions in several different years and graphically relating these measurements to concurrent flows at a nearby continuous-record station. In general, the results obtained from these regressions will give reliable estimates of median values (7-day $Q_2$) and less reliable estimates of more extreme events.

As shown in figure 26 and table 20, there is considerable variation in the values of the 7-day $Q_2$ for unregulated streams in the area. In general, the 7-day $Q_2$ for small unregulated tributary streams ranges from 0 to 0.005 cfs per square mile in the northern two-thirds of the area and from 0.02 to 0.05 cfs per square mile in the southern third of Jefferson County. The 7-day $Q_2$ for the Meramec and Big River basins is a relatively high 0.1 cfs per square mile. However, data from Coldwater Creek basin indicate that median low flows can be as great as 0.3 cfs per square mile in basins where sewage treatment plants are operating, depending on plant size, water-table condition, etc.

During 1967 and 1970, hydrologic data were collected on many of the tributary streams in the three-county area to determine low-flow gains or losses and to observe the impact of various urban developments on basin environment. Table 21 presents the results of discharge and specific-conductance measurements at various sites, plus observations of the streams' appearances and other information. The reconnaissance data from 1967 is especially useful because it was made during a period of

median low-flow conditions (7-day $Q_2$) over most of the area. Thus the data in the table can be a valuable guide concerning actual quantities of water available in many of the area's small surface streams during a specific drought. Water-quality information collected during these investigations is presented in appendix 4.

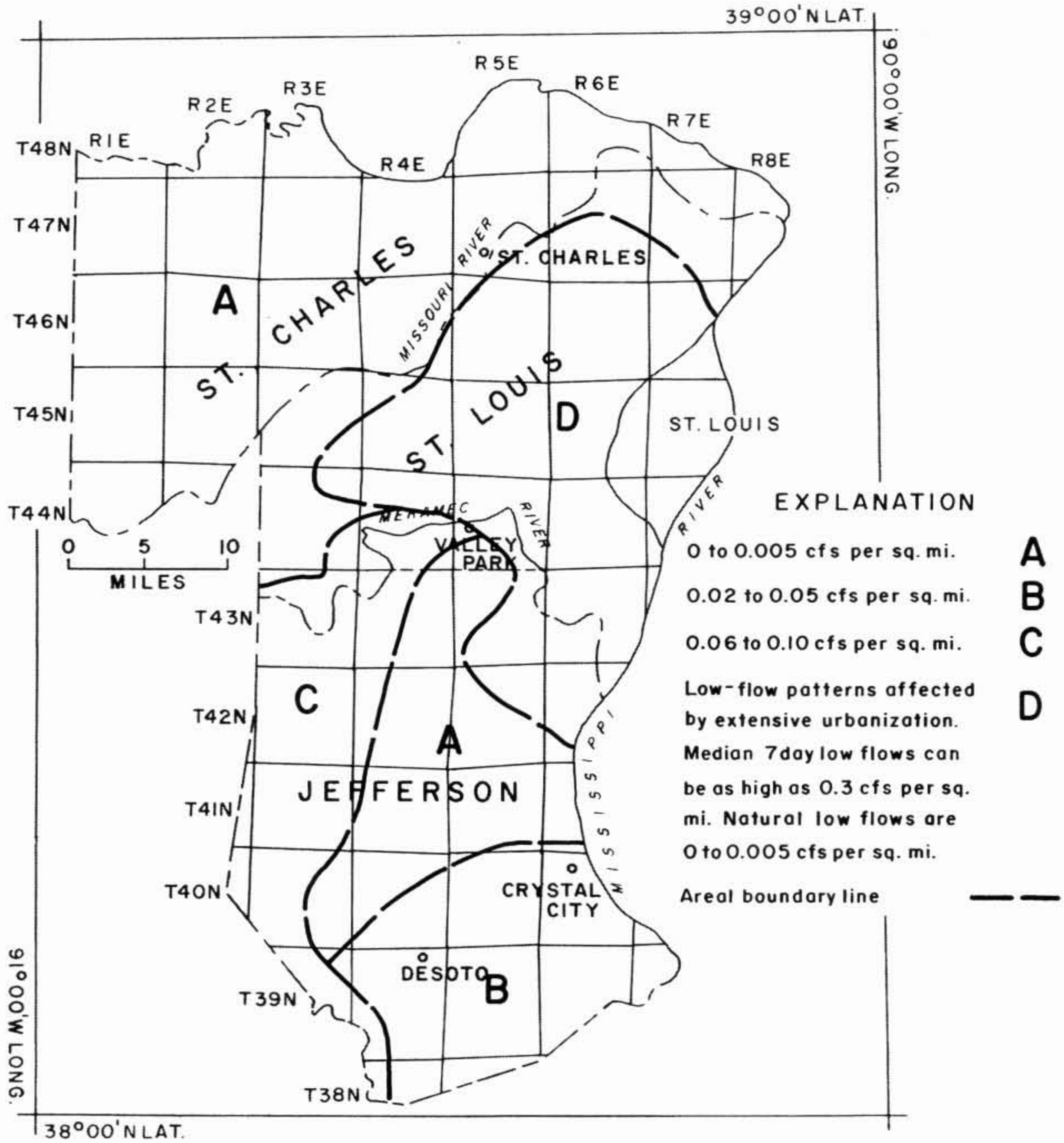



Figure 26

*Generalized patterns of median 7-day low-flow values for tributary streams. Recurrence interval of these data is 2 years.*

The specific conductance readings and descriptions of stream appearance in table 21 can be used to identify many of the streams in the area that are affected by urbanization and have low flows of inferior-quality water. For instance, the conductance of Bonhomme Creek at Chesterfield (fig. 2, map no. 26) was 500 micromhos and the water was described as very murky, with foam on the surface. Streamflow in undeveloped parts of the region was clear at the time and natural conductances were 400 micromhos or less; thus Bonhomme Creek was evidently affected by man's activities.

### EFFECTS OF URBANIZATION ON LOW FLOWS

Theoretically, urbanization will decrease the low flows of streams because of decreased soil-moisture storage, improvement of drainage, and lowering of groundwater levels (Ringenoldus and Bauer, written commun., 1966). James (1965) made a model analysis of a California streamflow record and found that the low flow of a completely urbanized basin is about 0.7 of the natural value.

In the St. Louis area, however, low flows of many small tributary streams having drainage areas of less than 50 square miles are greatly augmented, mostly by domestic effluents (figure 26, area D), and the net result is an increase in dry-weather flow. The natural low flow of most of these streams is less than 0.5 cfs (except in middle and southern Jefferson County). Consequently, an influx of poor-quality effluent, even though in small amounts, can seriously degrade the flow of an entire stream. Studies by Lutzen of the Missouri Geological Survey and Water Resources (written commun., 1970) in the Grand Glaize, Fishpot and Romaine Creek basins, point out specific examples of these effects.

## AUGMENTATION OF DEPENDABLE FLOWS BY STORAGE

In the tributary basins of the three-county study area, a lack of streams with natural sustained low flows makes it necessary to consider storage reservoirs when year-round surface-water supplies are required. The impoundments will generally serve a number of purposes such as recreation, low-flow augmentation and flood control. One of the more pressing problems involved in utilizing reservoirs in these developing areas, aside from the high cost of acquiring land, will be the pollution aspect of urban runoff during storms. It has been shown by Sheaffer and Zeizel (1966, p. 73) that the quality of initial storm runoff for some streams in urban areas is inferior to that of domestic sewage. Storage of this water would not only result in excessive treatment costs when the water is utilized, but would cause a generally unpleasant reservoir environment. Spieker (1970) stated that pollution loads may remain high in sluggish streams after several days of flooding because of accumulated sludge on the stream bottom and release of untreated sewage into the stream. Further analytical studies and continued management programs may be necessary in order to properly maintain these urban reservoirs.

For water managers and planners, there are some major points concerning impoundment of low flows in the St. Louis area that should be considered:

1. In almost all of the area, except for the larger tributary streams such as the Meramec, Big, and Cuivre Rivers, storage facilities are required to insure a dependable surface-water supply.

2. In urbanized areas of small natural flows, the quantity of low-flow may be adequate for some uses because of augmentation from treatment plants, sewers and septic tanks, but the quality of the water is very poor and thus extensive treatment is required prior to use.

3. Several miles of the lower reaches of many tributary streams are affected by backwater from the Mississippi and Missouri Rivers. In these ponded areas, water can be pumped directly from the streams with no need for impoundments to insure an adequate water level. The most important consideration in these reaches is, of course, the quality of the water, which may make it unsuitable for use without extensive treatment.

## Table 21

## Results of hydrologic reconnaissance on tributary streams

| Map no. (Fig. 2) | Station name | Location | Date | Discharge[a] (cfs) | Conductance (micromhos @ 25°C) | Dissolved oxygen (mg/l) | Water temperature (°C) | Air temperature (°C) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 2 | Big Creek near Moscow Mills | T. 48 N., R. 1 E., at bridge on U.S. Highway 61 at Lincoln-St. Charles County line, 4 miles south of Moscow Mills. | 9-12-67 | 0.2 | 500 | 9.5 | 21 | 27 | - |
| 3 | Cuivre River near Wentzville | T. 48 N., R. 2 E., 400 feet downstream from mouth of Big Creek, 4 miles northeast of Wentzville, Lincoln-St. Charles County line. | 9-12-67 | Pooled | 460 | 7.5 | 21 | 31 | Appears to be oil slick on water surface below mouth of Big Creek; muddy above. |
| 4 | Cuivre River near Old Monroe | NW¼ sec. 21, T. 48 N., R. 2 E., at fishing camp 3 miles southwest of Old Monroe, Lincoln-St. Charles County line. | 9-12-67 | Pooled | - | - | - | - | - |
| 5 | Cuivre River at Old Monroe | T. 48 N., R. 2 E., at bridge on State Highway 79 at Old Monroe, Lincoln-St. Charles County line. | 9-12-67 | Pooled | - | - | - | - | - |
| 6 | Peruque Creek at Foristell | SE¼ sec. 29, T. 47 N., R. 1 E., at bridge on County Highway T, 0.5 mile south of Foristell, St. Charles County. | 9-13-67 | 0 | - | - | - | - | Scattered shallow pools in channel. |
| | | | 11-4-70 | 4.4 | 460 | 10.5 | 7.0 | 4.0 | |
| 7 | Peruque Creek near Wentzville | SW¼ sec. 32, T. 47 N., R. 2 E., at bridge on county road 2 miles southeast of Wentzville, St. Charles County. | 9-13-67 | 0 | - | - | - | - | Shallow (less than 0.5 ft deep) pools with no flow. Scum on water surface below bridge. |
| | | | 11-4-70 | 14.4 | 450 | 10.5 | 7.5 | 4.0 | |
| 8 | Peruque Creek near Wentzville | S½ sec. 33, T. 47 N., R. 2 E., at bridge on U.S. Highway 61, 2.5 miles southeast of Wentzville, St. Charles County. | 9-12-67 | 0 | - | - | - | - | Pooled in vicinity of bridge. No discernible flow. |
| 9 | Peruque Creek near O'Fallon | SW¼ sec. 13, T. 47 N., R. 2 E., at bridge on County highway 3 miles west of O'Fallon, St. Charles County | 9-12-67 | 0 | - | - | - | - | Shallow pools with no flow. Oil film on water upstream from bridge. |
| 10 | Peruque Creek at O'Fallon | T. 47 N., R. 3 E., at bridge on State Highway 79, one mile northeast of O'Fallon, St. Charles County. | 9-12-67 | 0 | - | - | - | - | Pooled; no discernible flow. |
| | | | 11-4-70 | 11.9 | 480 | 9.3 | 7.0 | 8.0 | - |
| 11 | Dardenne Creek near New Melle | NW¼ sec. 23, T. 46 N., R. 1 E., at bridge on County Highway Z, 2 miles north of New Melle, St. Charles County. | 9-13-67 | Trickle (<.05) | - | - | - | - | Mostly scattered pools. Large piles of crushed lime on right bank below bridge. |
| 12 | Little Dardenne Creek near New Melle | SW¼ sec. 12, T. 46 N., R. 1 E., at bridge on County Highway Z, 4 miles north of New Melle, St. Charles County. | 9-13-67 | 0 | - | - | - | - | - |
| 13 | Dardenne Creek near New Melle | NE¼ sec. 21, T. 46 N., R. 2 E., at bridge on County Highway DD, 5 miles northeast of New Melle, St. Charles County. | 9-13-67 | 0.1 | - | - | - | - | - |
| | | | 11-3-70 | 16.5 | 360 | 10 | 9.0 | 6.0 | - |
| 14 | Dardenne Creek near Weldon Spring | T. 46 N., R. 3 E., at bridge on U.S. Highway 40 and 61, 3 miles northwest of Weldon Spring, St. Charles County. | 9-12-67 | 0.2 | 400 | 7.5 | 19 | - | Water clear |
| 15 | Dardenne Creek near Weldon Spring | SW¼ sec. 16, T. 46 N., R. 3 E., at bridge on County Highway K, 2 miles north of Weldon Spring, St. Charles County. | 9-12-67 | 0.2 | 400 | 7.5 | 19 | - | - |
| | | | 11-3-70 | 36.9 | 340 | 10.3 | 9.0 | 6.0 | - |
| 16 | Dardenne Creek at St. Peters | T. 47 N., R. 3 E., at bridge on County Highway C at St. Peters, St. Charles County. | 9-12-67 | 0 | - | - | - | - | Shallow pools with no flow. |
| 19 | Femme Osage Creek near Femme Osage | T. 45 N., R. 1 E., at bridge on county road 2 miles northeast of Femme Osage, St. Charles County. | 9-13-67 | 0 | 370 (in pool) | 6.5 (in pool) | 20 (in pool) | 25 (in pool) | Creek bed mostly dry but scattered pools contain small fish. The area is considerably more rugged from New Melle to this point than in other areas of the county, but the surface flow characteristics remain the same. |

## Table 21

## Results of hydrologic reconnaissance on tributary streams--continued

| Map no. (Fig. 2) | Station name | Location | Date | Discharge[a]/ (cfs) | Conductance (micromhos @ 25°C) | Dissolved oxygen (mg/l) | Water temperature (°C) | Air temperature (°C) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 20 | Callaway Fork near New Melle | SE¼ sec. 34, T. 46 N., R. 1 E., at bridge on County Highway F, 1.5 miles southwest of New Melle, St. Charles County. | 9-13-67 | 0 | - | - | - | - | - |
| 21 | Callaway Fork near Defiance | T. 45 N., R. 2 E., at bridge on County Highway F, 1.5 miles northwest of Defiance, St. Charles County. | 9-13-67 | 0.3 | 490 | 7.5 | 19 | 25 | Ninety-five percent of the flow originates in a small drain entering the creek 50 feet below a ford on county road in SW¼ sec. 16, T. 45 N., R. 2 E. Drain is choked with watercress with water temperature of 15°C and conductance of 490. |
| 22 | Femme Osage Creek near Weldon Spring | T. 45 N., R. 2 E., at bridge on State Highway 94, one mile north of Defiance and 7 miles southwest of Weldon Spring, St. Charles County. | 9-13-67 | 0.6 | 490 | 9 | 20 | 26 | - |
| 23 | Wild Horse Creek near Centaur | T. 45 N., R. 3 E., at bridge on Wildhorse Creek Road, 1 mile southwest of Centaur, St. Louis County. | 9-13-67 | Trickle (<0.05) | 440 | 5 | 21 | 28 | Water clear |
| 24 | Bonhomme Creek near Chesterfield | T. 45 N., R. 4 E., at bridge on County Highway CC, 2 miles west of Chesterfield, St. Louis County. | 9-13-67 | Trickle (<.01) | - | - | - | - | Isolated pools, virtually no flow. |
| 25 | Caulks Creek near Chesterfield | T. 45 N., R. 4 E., at bridge on County Highway CC, 1.5 miles southwest of Chesterfield, St. Louis County. | 9-13-67 | 1.4 (origin of Bonhomme Creek flow) | 530 | 8 | 18 | 25 | Small spring (0.1 cfs) 50 feet upstream from bridge has temperature of 13°C and conductance of 600 micromhos. Sewage lagoon and larger spring located in headwaters of this creek. |
| 26 | Bonhomme Creek at Chesterfield | T. 45 N., R. 4 E., at bridge on Olive St. Road at Chesterfield, St. Louis County | 9-13-67 | 1.5 | 500 | 11 | 23 | 31 | Water very murky in appearance with foam on surface. |
| 28 | Creve Coeur Creek at Creve Coeur | T. 46 N., R. 5 E., at bridge on Creve Coeur mill road 1 mile southwest of Creve Coeur, St. Louis County. | 9-13-67 | Trickle (<0.05) | 650 | - | 21 | - | - |
| 29 | Creve Coeur Lake at Creve Coeur | T. 46 N., R. 5 E., at Creve Coeur, St. Louis County. | 9-13-67 | - | 500 (SE shore of lake) | - | 23 (SE shore of Lake) | - | Foam floating on surface. Water dirty and full of debris. |
| 30 | Feefee Creek at Creve Coeur | T. 46 N., R. 5 E., at bridge on Creve Coeur mill road at Creve Coeur, St. Louis County. | 9-13-67 | 0.3 | - | - | - | - | Outflow from Creve Coeur Lake. |
| 37 | Fox Creek near Eureka | T. 43 N., R. 3 E., at bridge on U.S. Highway 66, 1.5 miles west of Eureka, St. Louis County. | 6-15-57 (indirect peak flow measurement) | 1,482 | - | - | - | - | - |
| | | | 9-13-67 | 0 | 500 (in pool) | - | 20 (in pool) | - | Isolated large, deep, clear pools are full of minnows. |
| 38 | La Barque Creek near Byrnesville | NW¼NW¼ sec. 34, T. 43 N., R. 3 E., at bridge on County Highway F, 2.5 miles northwest of Byrnesville, Jefferson County. | 9-30-53 | 0 | - | - | - | - | St. Peters sandstone outcrops along the stream. |
| | | | 9-15-67 | 0.5 | 340 | 8.5 | 20 | - | |
| 39 | Tiff Creek near Valles Mines (tributary to Cole Lake) | SW¼SW¼ sec. 11, T. 38 N., R. 4 E., at culvert on county road 4 miles southwest of Valles Mines, Jefferson County. | 9-15-67 | 0 | - | - | - | - | - |
| 40 | Cole Lake near Valles Mines | SE¼SE¼ sec. 10, T. 38 N., R. 4 E., 4 miles southwest of Valles Mines, Jefferson County. | 9-15-67 | - | 80 | 8to9.5 | 23 | 23 | Samples taken. |
| 40 | Cole Lake outflow | SE¼SE¼ sec. 10, T. 38 N., R. 4 E., 4 miles southwest of Valles Mines, Jefferson County. | 9-15-67 | 0.1 | 240 | - | 19 | - | Small amounts of watercress present in channel. May be part spring and part seepage from lake. |

## Table 21

### Results of hydrologic reconnaissance on tributary streams--continued

| Map no. (Fig. 2) | Station name | Location | Date | Discharge[a] (cfs) | Conductance (micromhos @ 25°C) | Dissolved oxygen (mg/l) | Water temperature (°C) | Air temperature (°C) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 41 | Unnamed creek near Valles Mines | NE¼ sec. 10, T. 38 N., R. 4 E., at bridge on County Highway E, 3½ miles southwest of Valles Mines, Jefferson County. | 9-15-67 | 0 | - | - | - | - | - |
| 44 | Dry Creek near Ware | NW¼ sec. 14, T. 40 N., R. 3 E., at bridge on County Highway Y, 1.5 miles south of Ware, Jefferson County. | 9-15-67 | Trickle (<0.02) | - | - | - | - | - |
| 45 | Dry Creek near Morse Hill | NW¼ sec. 26, T. 41 N., R. 3 E., at bridge on county road 1 mile southwest of Morse Hill, Jefferson County. | 9-15-67 | 0 | - | - | - | - | - |
| 46 | Belews Creek near Hillsboro | N½ sec. 17, T. 41 N., R. 4 E., at ford on county road, 4.5 miles northwest of Hillsboro, Jefferson County. | 9-15-67 | 0 | - | - | - | - | - |
| 47 | Inflow to Lake Tishomingo | NW¼ sec. 10 and SW¼ sec. 3, T. 41 N., R. 4 E., on county road 5.5 miles north of Hillsboro, Jefferson County. | 9-15-67 | 0 | - | - | - | - | - |
| 48 | Unnamed creek near Hillsboro | NE¼ sec. 4, T. 41 N., R. 4 E., at ford on county road 6 miles north of Hillsboro, Jefferson County. | 9-15-67 | 0 | - | - | - | - | - |
| 49 | Belews Creek tributary near Cedar Hill (outflow from Lake Tishomingo) | SE¼ sec. 31, T. 42 N., R. 4 E., at bridge on County Highway BB, 2.5 miles southeast of Cedar Hill, Jefferson County. | 9-15-67 | 0.5 | 320 | 8 | 20 | 24 | - |
| 51 | Heads Creek at House Springs | NE¼ sec. 4, T. 42 N., R. 4 E., at bridge on State Highway 30 at House Springs, Jefferson County. | 9-15-67 | 0 | - | - | - | - | Dry streambed with no pools. |
| 53 | Carr Creek at Glencoe | NE¼ sec. 24, T. 44 N., R. 3 E., at bridge on State Highway 109 at Glencoe, St. Louis County. | 9-13-67 | 0 | - | - | - | - | - |
| 54 | Keifer Creek near Ellisville | NW¼ sec. 9, T. 44 N., R. 4 E., at bridge on county road 1.5 miles south of Ellisville, St. Louis County. | 9-13-67 | 0 | - | - | - | - | - |
| 55 | Unnamed spring near Valley Park | NE¼ sec. 15, T. 44 N., R. 4 E., at bridge on county road 5 miles west of Valley Park, St. Louis County. | 9-13-67 | 0.1 | 520 | - | 13 | - | Flows into Keifer Creek. |
| 56 | Unnamed spring near Valley Park | NE¼ sec. 16, T. 44 N., R. 4 E., near county road 3.5 miles west of Valley Park, St. Louis County. | 9-13-67 | <0.01 | 490 | - | 14 | - | Flows into Spring Branch Creek. |
| 57 | Fishpot Creek at Winchester | W½ sec. 1, T. 44 N., R. 4 E., at bridge on county road at Winchester, St. Louis County. | 9-13-67<br>6-16-70 | 0<br>0.5 | -<br>380 | -<br>- | -<br>- | -<br>- | -<br>Flow disappears about 400 yards downstream. Indicates zone of water losses. |
| 58 | Grand Glaise Creek near Kirkwood | SE¼ sec. 4, T. 44 N., R. 5 E., at bridge on Dougherty Ferry road 1.5 miles west of Kirkwood, St. Louis County. | 9-13-67<br>6-16-70 | 2.0<br>8.3 | 950<br>650 | -<br>- | -<br>25 | -<br>34 | Foam on surface, smells of sewage no fish seen. |
| 60 | Romaine Creek at Paulina Hills | E½ sec. 14, T. 43 N., R. 5 E., at bridge on State Highway 141 at Paulina Hills, Jefferson County. | 11-4-70 | 3.7 | 500 | 10 | 9.0 | 6.5 | Black precipitant on bottom of creek. Slight sewage odor. |
| 62 | Mattese Creek near Oakville | NE¼ sec. 15, T. 43 N., R. 6 E., at bridge on Old Baumgartner Road, 1.5 miles west of Oakville, St. Louis County. | 9-14-67 | 2.4 | 750 | 1.5 | 20.5 | 23 | Foam on surface. Affected by sewage or plant effluent. |

## Table 21

## Results of hydrologic reconnaissance on tributary streams--continued

| Map no. (Fig. 2) | Station name | Location | Date | Discharge[a] (cfs) | Conductance (micromhos @ 25°C) | Dissolved oxygen (mg/l) | Water temperature (°C) | Air temperature (°C) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 63 | Rock Creek at Kimmswick | T. 42 N., R. 6 E., at bridge on county highway 0.5 mile west of Kimmswick, Jefferson County. | 9-14-67 | 0.3 | 590 | 6 | 20 | - | - |
| 64 | Glaize Creek near Kohler City | T. 42 N., R. 6 E., at bridge on county highway 1.5 miles northwest of Kohler City, Jefferson County. | 9-14-67 | 0.8 | 500 | 9 | 21 | - | Mud bottom with small amounts of gravel. |
| 65 | Joachim Creek at De Soto | On line between secs. 10 and 11, T. 39 N., R. 4 E., at bridge on County Highway E at De Soto, Jefferson County. | 9-14-67<br>11-5-70 | 1.7<br>14.9 | 430<br>460 | 9.5<br>10.6 | 24.5<br>7.0 | 30<br>6.5 | -<br>- |
| 66 | Otter Creek near Hillsboro | SE¼ sec. 22, T. 40 N., R. 4 E., at bridge on State Highway 21, 3 miles south of Hillsboro, Jefferson County. | 9-14-67 | 0 | - | - | - | - | A few scattered pools. |
| 67 | Joachim Creek at Hematite[b] | NW¼ sec. 16, T. 40 N., R. 5 E., at bridge on county highway at Hematite, Jefferson County. | 9-14-67<br>11-5-70 | 5.1<br>20.4 | 540<br>570 | 8.5<br>8.9 | 23<br>7.5 | 30<br>7.0 | Water clear. Samples taken. |
| 68 | Lake Wauwanoka near Hillsboro | In secs. 1 and 2, T. 40 N., R. 4 E., 2 miles east of Hillsboro, Jefferson County. | 9-14-67 | outflow at dam - 0.9 | - | - | - | - | Earth-fill dam was leaking at this time. Lake was about 10 percent full. Major sources of water for this lake are several springs which merge near the dam. |
| 69 | South Fork Little Creek near Hillsboro | SE¼ sec. 1, T. 40 N., R. 5 E., at bridge on county road 2.5 miles southeast of Hillsboro, Jefferson County. | 9-14-67 | 1.8 | 340 | 9 | 23 | 30 | Water clear. This stream contains the outflow from Lake Wauwanoka. |
| 70 | North Fork Little Creek near Hillsboro | S½ sec. 31, T. 41 N., R. 5 E., at bridge on county road 2.5 miles east of Hillsboro, Jefferson County. | 9-14-67 | 0 | - | - | - | - | - |
| 71 | Little Creek near Hematite | NE¼ sec. 5, T. 40 N., R. 5 E., at bridge on county road 2 miles north of Hematite, Jefferson County. | 9-14-67 | 2.5 | 350 | 9.5 | 24 | 32 | Water clear. Samples taken. |
| 72 | Joachim Creek near Festus | NW¼ sec. 1, T. 40 N., R. 5 E., at bridge on County Highway A, 1.5 miles west of Festus, Jefferson County. | 9-15-67 | 7.4 | 500 | 8 | 20 | 19 | - |
| 73 | Sandy Creek at Pevely[b] | T. 41 N., R. 5 E., at bridge on County Highway Z, 1 mile west of Pevely, Jefferson County. | 9-14-67 | 0.2 | 550 | 9 | 21 | - | Sand-bottom channel. No rock outcrops visible. |
| 74 | Joachim Creek near Pevely | T. 41 N., R. 6 E., at bridge on U.S. Highway 61, 1.5 miles south of Pevely, Jefferson County. | 9-14-67 | Ponded | - | - | - | - | Backwater from Mississippi River. |
| 75 | West Fork Plattin Creek near Papin | NE¼NE¼ sec. 25, T. 39 N., R. 5 E., at ford on county road 3 miles east of Papin, Jefferson County. | 9-14-67 | 2.6 | 450 | 10 | 22 | 26 | Water clear. |
| 76 | Plattin Creek at Plattin | T. 39 N., R. 6 E., at bridge on county road at Plattin, Jefferson County. | 11-5-70 | 14.9 | 460 | 11.4 | 13.5 | 7.0 | - |
| 77 | Plattin Creek near Crystal City | T. 40 N., R. 6 E., at bridge on U.S. Highway 61, 3 miles south of Crystal City, Jefferson County. | 9-14-67 | 4.9 | 460 | 9.5 | 21 | 23 | Samples taken. |
| 80 | Isle du Bois Creek near Festus | T. 39 N., R. 7 E., at bridge on County Highway TT, 10 miles southeast of Festus, Jefferson County. | 9-14-67 | 0 | - | - | - | - | - |

a/ 1967 data were collected during a period of median low-flow conditions (7-day $Q_2$).

b/ Continuous-record station.

Table 22

Draft-storage frequency data at continuous and partial-record stations

| Map no. (Fig. 2) | Station name | Record used in analysis | Drainage area (sq mi) | Draft-storage frequency: Percent chance of deficiency[a] | Amount of storage (in thousands of acre-feet) for draft rate (in cfs) indicated in column headings (not corrected for reservoir evaporation, sedimentation, and seepage)[b] | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Cuivre River near Troy | 1924-69 | 903 | | 25 cfs | 140 cfs | 260 cfs | 380 cfs | 500 cfs |
| | | | | 2 | 15 | 140 | 290 | 540 | 1,100 |
| | | | | 5 | 10 | 75 | 180 | 390 | 870 |
| | | | | 10 | 6 | 65 | 170 | 320 | 640 |
| 2 | Big Creek near Moscow Mills | 1962-64, 1967 | - | | 12 cfs | 24 cfs | 48 cfs | 60 cfs | 72 cfs |
| | | | | 2 | 7 | 18 | 58 | 95 | 175 |
| | | | | 5 | 5 | 11 | 38 | 66 | 134 |
| | | | | 10 | 2 | 8 | 28 | 61 | 110 |
| 7 | Peruque Creek near Wentzville | 1942-43, 1945-46, 1948, 1953, 1962-63, 1967 | - | | 5 cfs | 10 cfs | 20 cfs | 30 cfs | 35 cfs |
| | | | | 2 | 3 | 7 | 22 | 64 | - |
| | | | | 5 | 2 | 4 | 14 | 50 | - |
| | | | | 10 | 1 | 3 | 12 | 40 | 64 |
| 14 | Dardenne Creek near Weldon Spring | 1942-43, 1945-46, 1948, 1953, 1961-63, 1967 | - | | 5 cfs | 10 cfs | 20 cfs | 30 cfs | 35 cfs |
| | | | | 2 | 3 | 7 | 22 | 64 | - |
| | | | | 5 | 2 | 4 | 14 | 50 | - |
| | | | | 10 | 1 | 3 | 12 | 40 | 64 |
| 22 | Femme Osage Creek near Weldon Spring | 1961-63, 1967 | - | | 6 cfs | 18 cfs | 24 cfs | 36 cfs | 42 cfs |
| | | | | 2 | 4 | 14 | 26 | 71 | - |
| | | | | 5 | 3 | 8 | 17 | 57 | 91 |
| | | | | 10 | 1 | 7 | 12 | 44 | 72 |
| 42 | Big River near De Soto | 1950-69 | 718 | | 195 cfs | 300 cfs | 390 cfs | 500 cfs | 630 cfs |
| | | | | 2 | 70 | 260 | 480 | 830 | 2,000 |
| | | | | 5 | 45 | 180 | 320 | 610 | 1,400 |
| | | | | 10 | 35 | 120 | 260 | 510 | 1,040 |
| 43 | Big River near Richwoods | 1942-43, 1946-47, 1951, 1961-65, 1969 | - | | 222 cfs | 300 cfs | 370 cfs | 444 cfs | 518 cfs |
| | | | | 2 | 148 | 275 | 408 | 615 | 1,050 |
| | | | | 5 | 74 | 190 | 282 | 489 | 763 |
| | | | | 10 | 52 | 134 | 222 | 356 | 586 |
| 50 | Big River at Byrnesville | 1923-69 | 917 | | 225 cfs | 350 cfs | 500 cfs | 600 cfs | 730 cfs |
| | | | | 2 | 75 | 220 | 460 | 750 | 1,550 |
| | | | | 5 | 50 | 160 | 375 | 575 | 1,180 |
| | | | | 10 | 35 | 100 | 280 | 460 | 880 |
| 52 | Meramec River near Eureka | 1922-69 | 3,788 | | 750 cfs | 1,200 cfs | 1,600 cfs | 2,100 cfs | 2,600 cfs |
| | | | | 2 | 160 | 650 | 1,300 | 2,500 | 5,600 |
| | | | | 5 | 80 | 500 | 1,100 | 2,000 | 4,200 |
| | | | | 10 | 75 | 320 | 700 | 1,500 | 3,100 |
| 67 | Joachim Creek at Hematite | 1961-65, 1967-69 | 95.0 | | 19 cfs | 38 cfs | 58 cfs | 66 cfs | 76 cfs |
| | | | | 2 | 10 | 33 | 70 | 108 | - |
| | | | | 5 | 4 | 21 | 57 | 84 | 140 |
| | | | | 10 | 3 | 12 | 41 | 66 | 104 |

a/ Percent chance of deficiency indicates the percent of years in which a storage reservoir of indicated capacity would become empty.

b/ Amounts of storage listed are hydrologically feasible. The physical limitations of the terrain have not been analyzed.

Table 22 contains draft-storage frequency data for gaging stations in the St. Louis area. These data were computed by the mathematical technique of Markov chain analysis called probability routing, as described in a report by Skelton (1971).

Note that the frequency characteristics are expressed as percent chance of deficiency. This value indicates the percent of years in which a reservoir of indicated capacity will become empty. It also can be interpreted as the average chance of having an empty reservoir in any year over a long period of years. However, this does not mean that a deficiency is equally probable in each year, because a series of dry years will decrease the amount of water stored and increase the chance of deficiency in succeeding years.

The draft-storage data are useful primarily in making preliminary estimates of potential development and in comparing development possibilities of different streams. However, for small, multipurpose reservoirs, the data may be adequate for final design purposes.

Regional draft-storage curves for a 2-percent chance of deficiency were developed from long-time streamflow records in eastern Missouri and are presented in figure 27. These curves can be used to estimate storage requirements at ungaged sites or gaging stations where records are short or inadequate. The standard errors of estimate for the regional curves were determined graphically and found to be 20 percent or less.

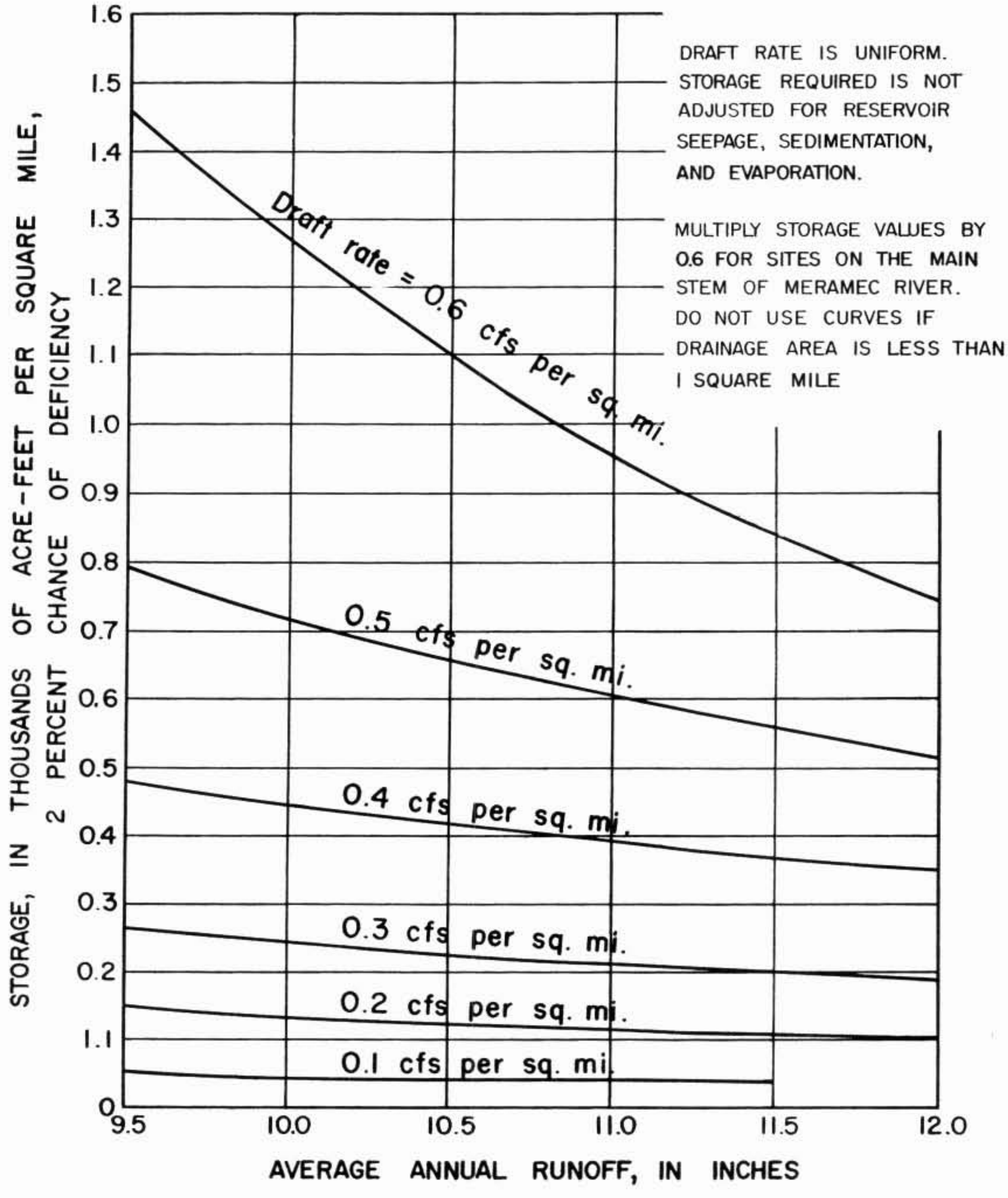



**Figure 27**

*Regional draft-storage curves for the St. Louis area.*

### APPLICATION OF REGIONAL DRAFT-STORAGE CURVES

In most cases, proposed reservoir sites are located where long streamflow records are not available. Therefore, the regional draft-storage curves of figure 27 should be utilized in making estimates. The following steps are necessary in making estimates of storage requirements at ungaged sites:

1. Determine the drainage area upstream from the site, using the best available topographic map.

2. Determine average annual runoff for the basin to the nearest inch from figure 24. Use the center of the basin as the point of estimation.

3. Use the regional curves to estimate storage requirements. The estimates will be somewhat conservative; the average chance of the reservoir becoming empty in any year is 2 percent.

4. Where significant urbanization exists, the storage requirements obtained from the regional curves should be computed using adjusted values of mean flows to account for the increased runoff volumes from urbanized areas. Suggestions for these adjustments are presented in the section "Effects of Urbanization on Mean Flows."

### RESERVOIR LOSSES

For this report no adjustments have been made to station data or regional curves for reservoir losses due to evaporation, seepage or sedimentation. A detailed discussion of regional adjustments to storage requirements for these losses is presented by Skelton (1968, p. 15-23). This information will be useful in preliminary studies; however, a more detailed analysis will be necessary at the reservoir site prior to construction of major structures.

### LIMITATIONS OF DATA

Before station data and regional draft-storage curves are used in project planning, the following limitations should be considered:

1. Regional curves and station data should not be extrapolated beyond the limits shown.

2. Regional curves are not applicable to streams significantly regulated by reservoirs or to the Mississippi and Missouri Rivers.

3. Regional curves should not be used for drainage areas of less than one square mile.

4. In the Ozarks part of the study area (fig. 1), field reconnaissance of potential reservoir sites is necessary to avoid gross underestimation of storage requirements. In this region, there is a possibility that small basins and reaches of some streams may have zones of significant water losses which were not discovered during hydrologic investigations of the region (see table 21). Special studies would be required to define storage requirements in water-loss areas and to determine if reservoirs are structurally feasible.

## QUALITY OF SURFACE WATER

The St. Louis area is nearly surrounded by large streams. The Missouri River to the north, the Mississippi River to the east, and the Meramec River to the south make available an almost unlimited supply of surface water. Many of the water-supply and waste-disposal needs of the area are met by these streams. Because of their large flow, these streams are able to assimilate large amounts of wastes. Uses of the water, however, are limited when extensive and costly treatment is needed to obtain the desired quality.

Municipal, industrial, agricultural and other wastes entering streams anywhere in the north-central part of the United States influence the quality of water in the Missouri and Mississippi Rivers in the St. Louis area. Not all of man's activities, however, have caused deterioration of the quality of water in these rivers. For instance, impoundments on the Missouri River main stem and tributaries over the past 20 years have resulted in a significant decrease in turbidity, an undesirable characteristic of Missouri River water.

The map of the study area, figure 2, includes locations of U.S. Geological Survey stream-sampling sites and water plants which are the source of data for this report.

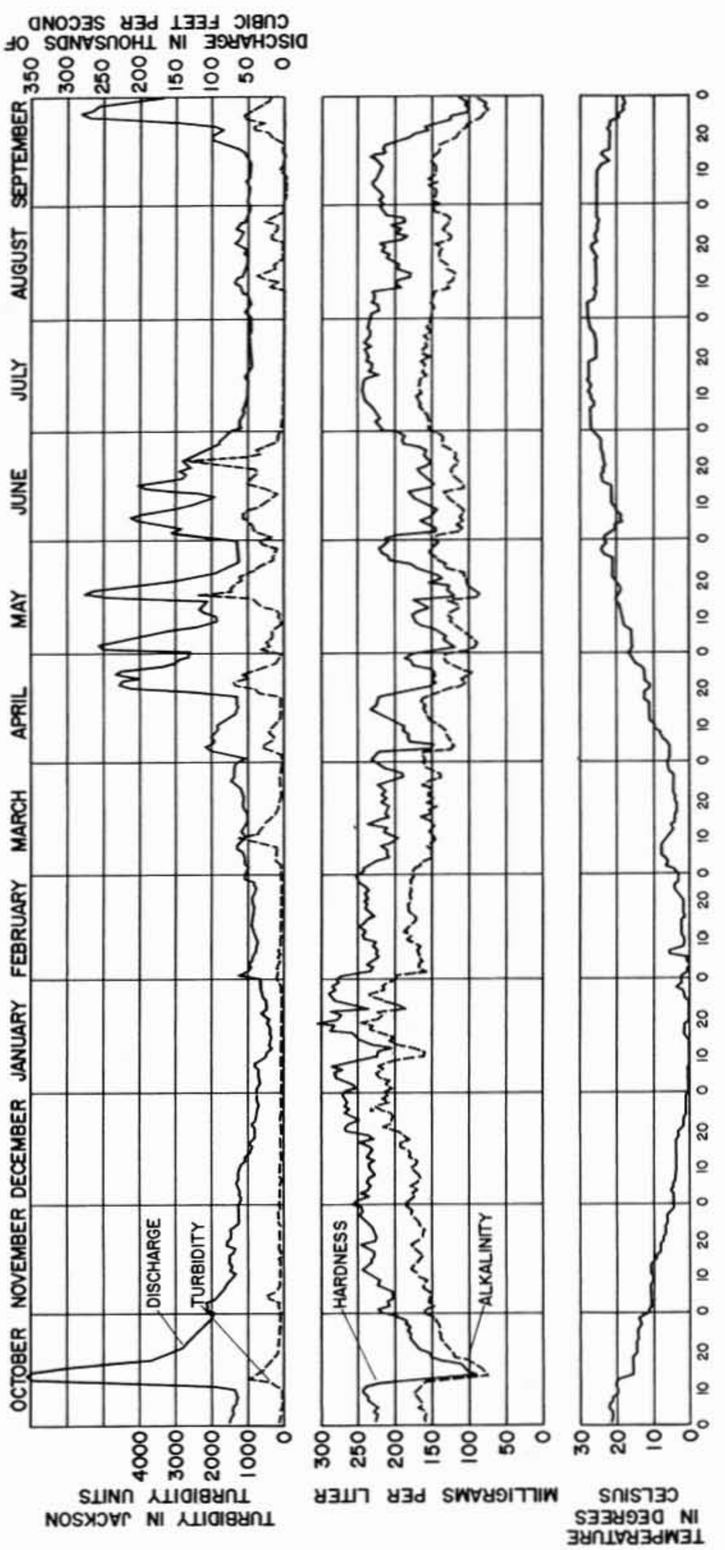



Figure 28

*Relation between discharge and chemical and physical characteristics of water from the Missouri River at Howard Bend Plant near St. Louis, Mo., 1969-70.*

## MISSOURI RIVER

Water in the Missouri River near St. Louis is moderately mineralized. The predominant chemical constituents are calcium, magnesium, sodium, bicarbonate and sulfate. Variations in dissolved-solids content are primarily caused by variations in the amounts of these constituents. Although a downward trend in turbidity has been observed in recent years, turbidity is still relatively high, and the water must be treated for most uses. Generally, the water is hard and this undesirable characteristic contributes to the need for treatment before use.

Daily changes in selected chemical and physical characteristics at the City of St. Louis Howard Bend Water Plant (fig. 2, map no. 27) are related to the discharge record from the gage at Hermann, Mo., for the 1970 water year in figure 28. Water temperature varied from 0.0 degrees Celsius (centigrade) in January and February to 29.0°C in July and August. Turbidity varied from 20 JTU (Jackson turbidity units) in January to 2,400 JTU in May with a median for the year of 135. Turbidity fluctuates rather closely with streamflow; therefore, turbidity is generally lower during winter when streamflow is low and higher during the spring and summer when streamflow is high. Alkalinity and hardness as $CaCO_3$ ranges from 76 and 89 mg/l respectively during the high water in October to high values of 243 and 303 mg/l in January.

Alkalinity and hardness vary inversely with streamflow and generally have higher values in the winter.

Ranges in chemical and physical characteristics of daily samples collected at Howard Bend for the 20-year period 1951-70 are summarized in table 23. During this period the average concentration of dissolved solids was 382 mg/l as compared to 365 mg/l reported for the 10-year period 1940-49 (Searcy, Baker and Durum, 1952).

Average monthly characteristics for the 20-year period, figure 29, include temperature variations from 2.0°C in January to 27.0°C in July. The long-term relationship in this figure follows the short-term relationship in figure 28. Dissolved solids, alkalinity and hardness were lowest in the summer when streamflow was high and highest during the winter when streamflow was low.

Annual average turbidity and annual average discharge for the period 1951-70 are plotted in figure 30. Turbidity decreased from an average of 1,002 JTU for the 5-year period 1951-55 to 361 for 1966-70. Discharge averaged the same for both periods, 77,000 cfs. Turbidity averaged 694 JTU for the 20-year period 1951-70, as compared to 1,670 JTU for the 10-year period 1940-49 (Searcy, Baker and Durum, 1952).

The double-mass curves in figure 31 show a decrease in turbidity and sediment, with the most

Table 23

Selected chemical and physical characteristics of water from the Missouri River at Howard Bend Plant near St. Louis, Mo., 1951-70
[analyses by City of St. Louis]

| Characteristics | Minimum | Mean | Maximum |
|---|---|---|---|
| Temperature (°C)---------- | 0 | 14.5 | 31.0 |
| pH----------------------- | 7.5 | 8.1 | 9.6 |
| Alkalinity as $CaCO_3$ (mg/l) | 53 | 150 | 294 |
| Hardness as $CaCO_3$ (mg/l) | 83 | 206 | 366 |
| Turbidity (JTU)----------- | 5 | 694 | 12,000 |

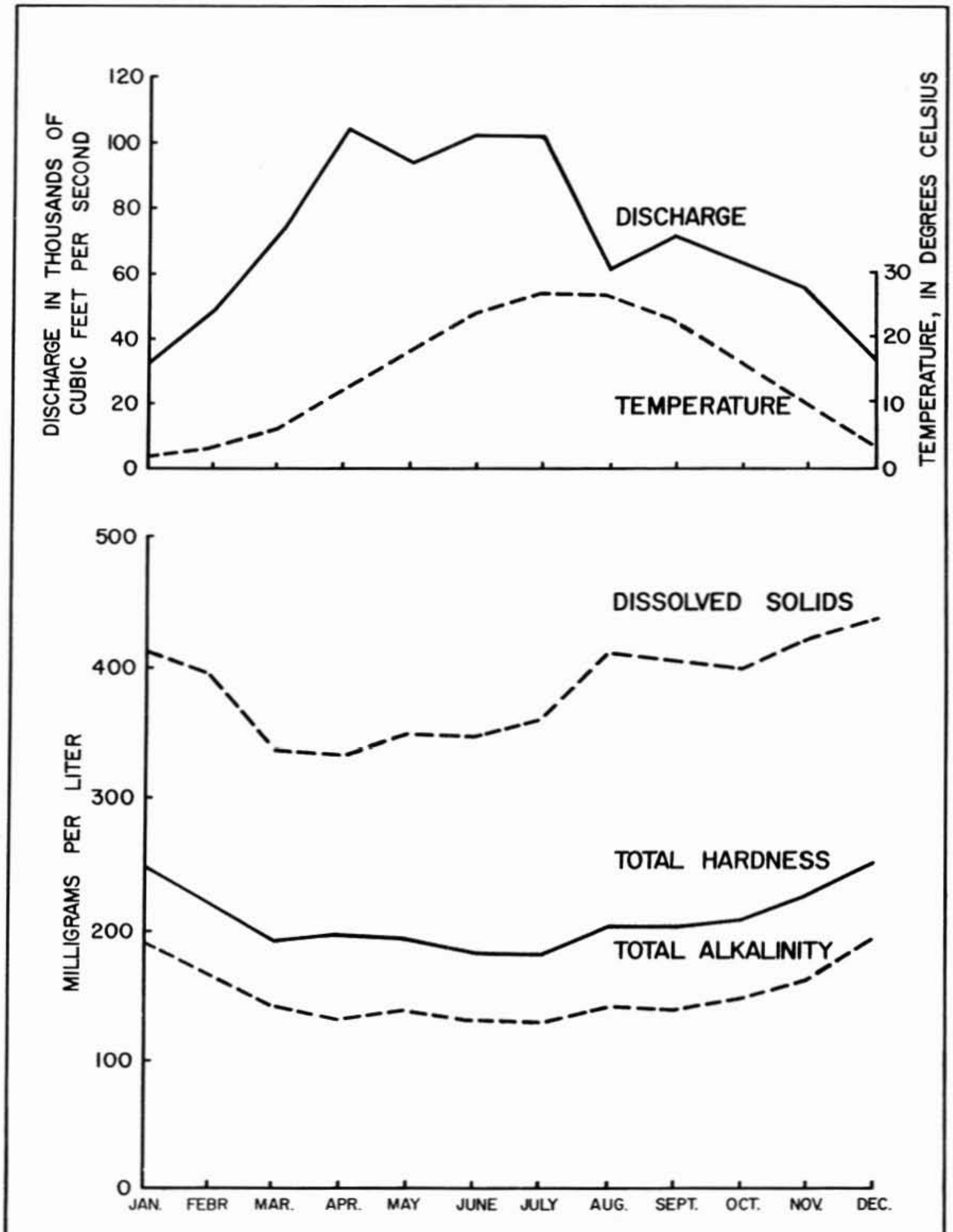



Figure 29
*Average monthly chemical and physical characteristics of water from the Missouri River at Howard Bend Plant near St. Louis, Mo., 1951-70.*

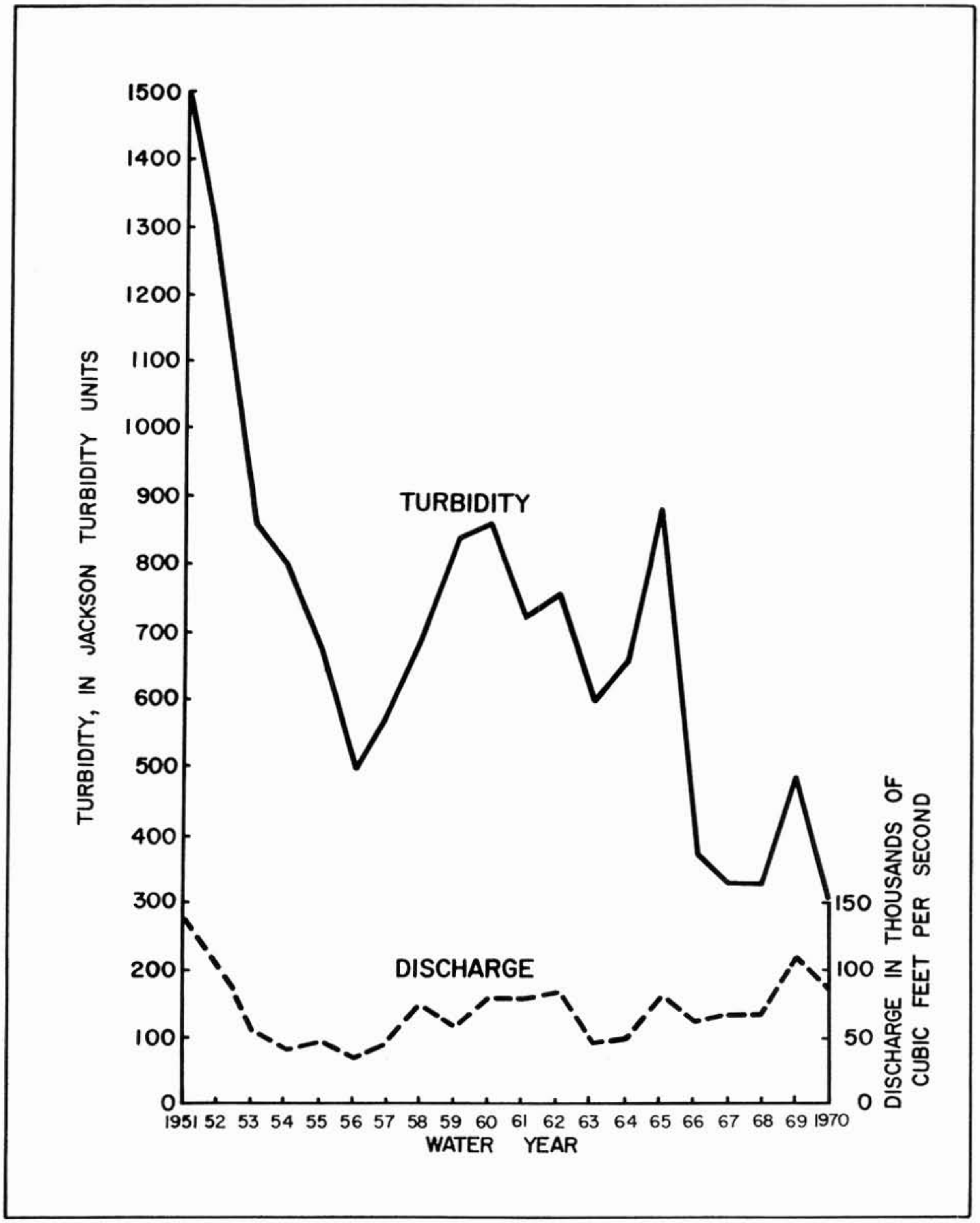



Figure 30

*Annual average turbidity and discharge of the Missouri River at Howard Bend Plant near St. Louis, Mo., 1951-70.*

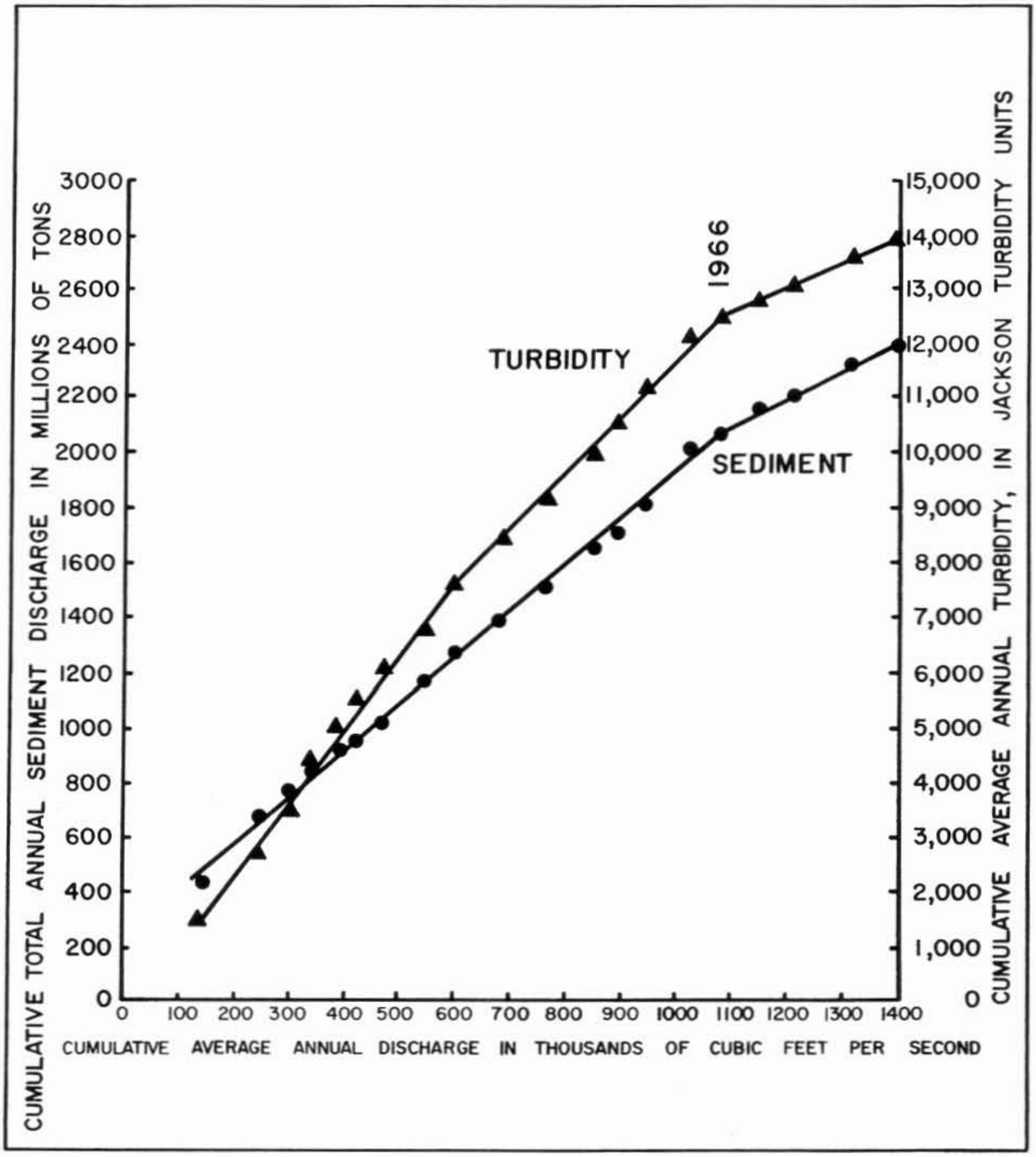



**Figure 31**

*Double-mass curve of turbidity and sediment versus discharge for the Missouri River at Howard Bend Plant near St. Louis, Mo., 1951-70.*

Table 24

Selected chemical and physical characteristics of water from the Mississippi River at Alton, Ill., 1970
[analyses by Alton Water Co.]

| Characteristic | Minimum | Median | Maximum |
|---|---|---|---|
| Temperature (°C)--------- | 0 | 12.5 | 29.5 |
| pH---------------------- | 7.7 | 8.1 | 8.6 |
| Alkalinity as $CaCO_3$ (mg/l) | 87 | 168 | 205 |
| Hardness as $CaCO_3$ (mg/l) | 118 | 235 | 304 |
| Turbidity (JTU)---------- | 12 | 40 | 875 |

significant change occurring about 1966. The sediment record was collected at Hermann, Mo., by the U.S. Army Corps of Engineers, Kansas City District. Federal impoundments constructed on the Missouri River's main stem and tributaries (numbering about 50) and control structures on the Missouri River are apparently responsible for the decrease in turbidity and sediment. However, the actual effectiveness of the impoundments for sediment removal is difficult to evaluate because of the inexact relationship of sediment to streamflow. Jordan (1968) attempted to separate the effects of streamflow from those of the impoundments. The results were based on data for years prior to 1964 and indicated that impoundments caused a 25- to 30-percent reduction in sediment discharge for the Missouri River at Kansas City. The influence would be less for stations downstream from Kansas City because of fewer impoundments downstream. More impoundments have been completed since Jordan's analysis and apparently have caused further decrease in sediment discharge. As more impoundments are constructed, especially in the uncontrolled sediment-laden tributaries downstream from Kansas City, sediment and turbidity should continue to decrease in the St. Louis area.

Appendix 5 is a compilation of annual average values of several water-quality characteristics of the Missouri River at the City of St. Louis Howard Bend Water Plant for the period April 1951 to March 1970. Total coliform bacteria averaged about 5,900 col/100 ml (colonies per 100 milliliters) for the first 5 years and about 14,000 col/100 ml for the last 5 years of the period.

## MISSISSIPPI RIVER

### UPSTREAM FROM THE MISSOURI RIVER

Mississippi River water at the Alton Water Plant (fig. 2, map no. 17), about 9 miles upstream from the mouth of the Missouri River, is generally of good quality and suitable for most uses. The water, which is moderately mineralized, is a calcium-bicarbonate type and contains significant amounts of magnesium and sulfate in the dissolved solids. Although turbidity is relatively low upstream from the Missouri River, the water is very hard and some treatment such as softening would be desirable for municipal and some industrial uses.

The relation between discharge and some water-quality characteristics at Alton are illustrated in figure 32 for the 1970 water year. Turbidity reached undesirable levels only a few times during the high streamflow of spring and fall.

Ranges in chemical and physical characteristics of daily samples collected during the 1970 water year are listed in table 24.

Total coliform bacteria counts made by the Alton Water Company on 26 samples collected from September to December 1970 ranged from 2,000 to 64,000, with a median of 11,000 col/100 ml.

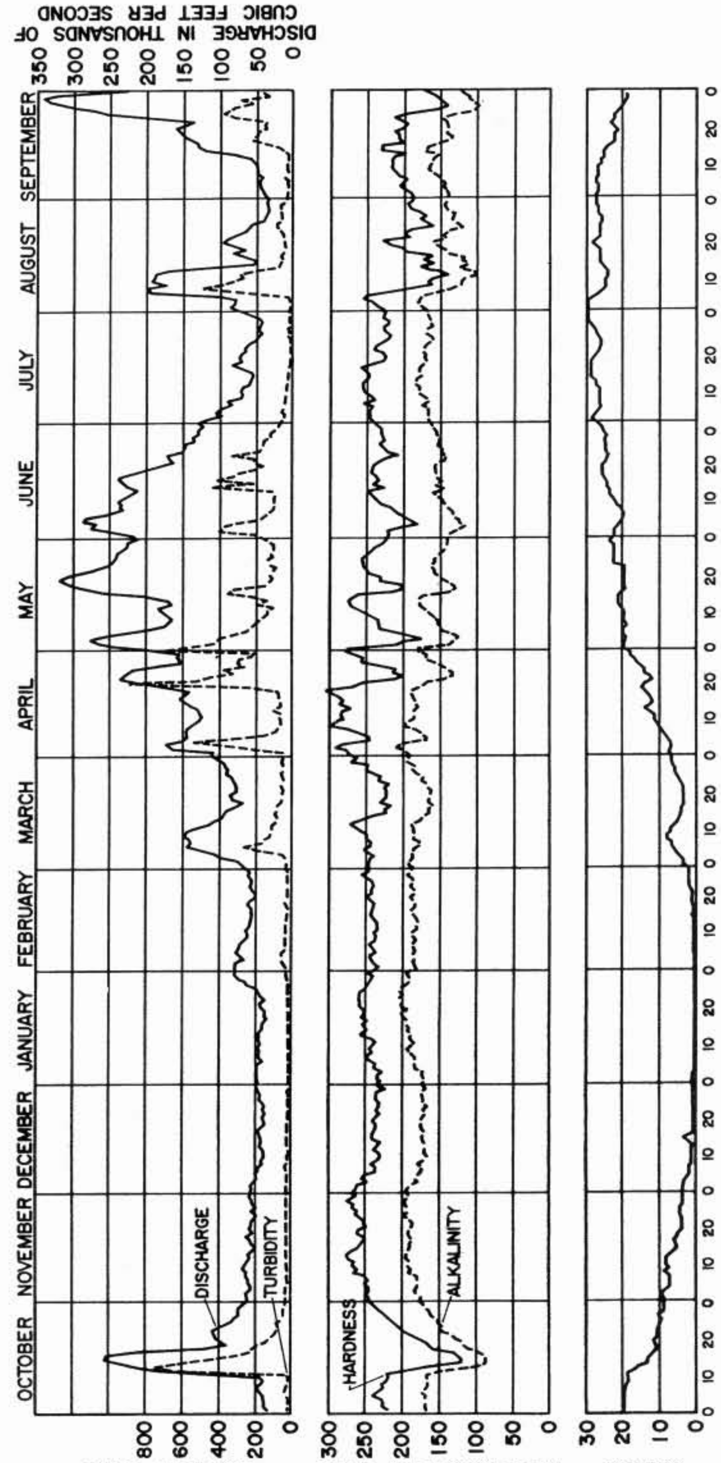



Figure 32

*Relation between discharge and chemical and physical characteristics of Mississippi River at Alton, Ill., 1969-70.*

Table 25

Selected chemical and physical characteristics of water from the Mississippi River at Chain of Rocks Plant in St. Louis, Mo., 1951-70 [analyses by City of St. Louis]

| Characteristic | Minimum | Mean | Maximum |
|---|---|---|---|
| Temperature (°C)---------- | 0 | 14.5 | 32.0 |
| pH----------------------- | 7.2 | 8.0 | 9.0 |
| Alkalinity as $CaCO_3$ (mg/l) | 72 | 147 | 290 |
| Hardness as $CaCO_3$ (mg/l) | 89 | 204 | 323 |
| Turbidity (JTU)----------- | 8 | 608 | 6,000 |

**DOWNSTREAM FROM THE MISSOURI RIVER**

Inflow from the Missouri River during periods of low flow does not mix completely for several miles downstream. As a result, water-quality records at the Chain of Rocks Water Plant (fig. 2, map no. 33), about 5 miles downstream from the confluence with the Missouri, are indicative of Missouri River inflow. The water on the opposite (east) side of the river is about the same quality as water in the Mississippi River upstream from the confluence.

Daily variations of selected characteristics of Mississippi River water at Chain of Rocks for the 1970 water year are illustrated in figure 33. Temperature ranged from 0.0°C in January to 29.5°C in July and August. Alkalinity as $CaCO_3$ varied from 83 mg/l in September and October to 241 mg/l in January. Hardness as $CaCO_3$ ranged from 105 mg/l in October to 296 mg/l in January. Turbidity varied from 10 JTU in January to 4,000 JTU in May. The median turbidity was 160 JTU, as compared to a median of 40 JTU for the same period at Alton. Inflow from the Missouri River is responsible for the increased turbidity in the Mississippi, especially during periods of high flow in the Missouri River.

Ranges in chemical and physical characteristics of daily samples at Chain of Rocks are summarized in table 25 for the 20-year period October 1950 to September 1970. The average dissolved-solids content for the period was 373 mg/l. This compares to an average of 340 mg/l for the 10-year period 1940-49 (Searcy, Baker and Durum, 1952). The dissolved solids are primarily composed of bicarbonates and sulfates of calcium and sodium.

Average monthly water temperature, figure 34, ranged from 2.0°C for January to 26.5°C for August. Dissolved solids, alkalinity and hardness were lowest in the summer when streamflow was high and highest during the winter when streamflow was low.

As shown in figure 35 annual average discharge was relatively uniform for the period 1951-70, while turbidity dropped from an average of 880 JTU for the first 5 years to an average of 355 JTU for the last 5 years of the period.

Double-mass curves of turbidity and sediment versus streamflow are plotted in figure 36 for the years 1951-70. A decided break in slope is noted about 1966, which indicates a significant decrease in turbidity and sediment since that time. This decrease was caused mainly by the completion of control structures in the upper Missouri River basin, as described in the previous section on the Missouri River.

Annual average values of several characteristics of Mississippi River water at Chain of Rocks for the period April 1951 to March 1970 are compiled in appendix 6. The bacteria data indicate that total coliform bacteria counts averaged about 9,500 col/100 ml for the years 1951-55, and about 27,000 col/100 ml for the years 1966-70.

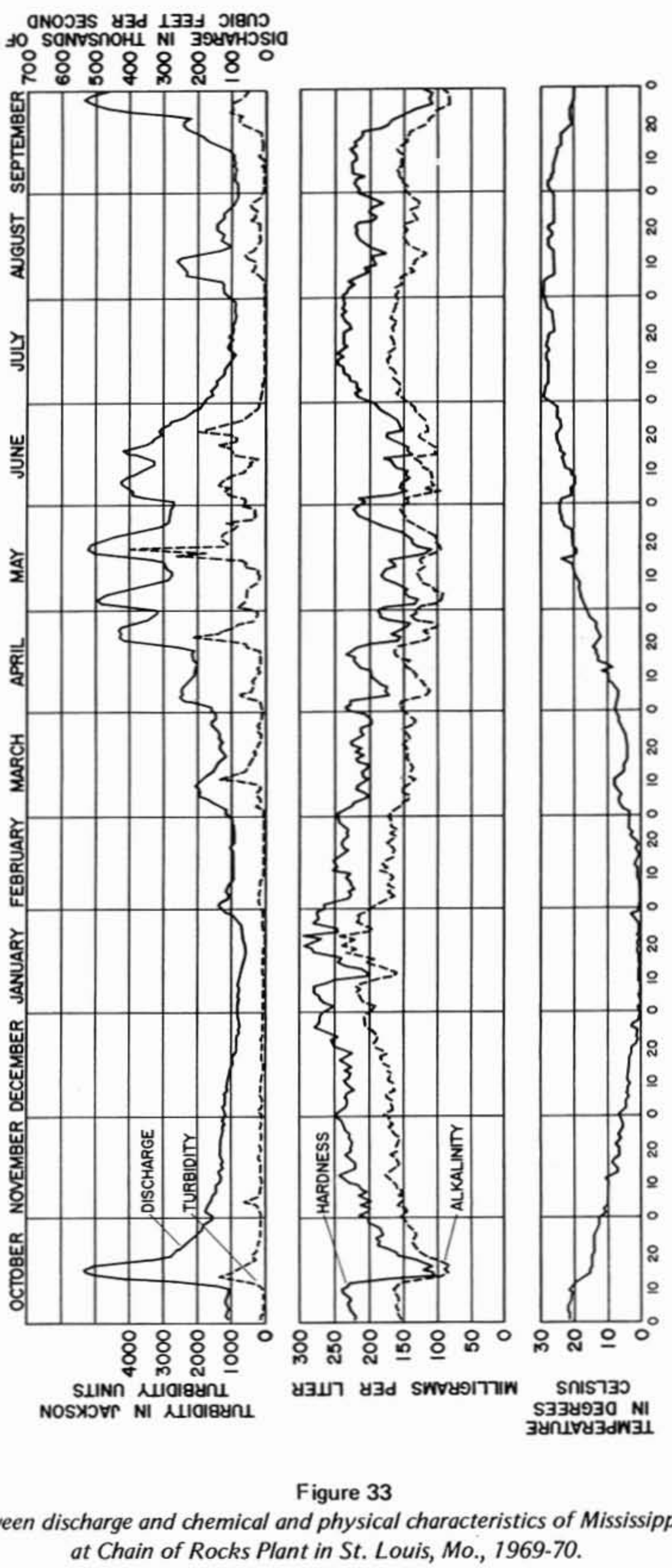



Figure 33

*Relation between discharge and chemical and physical characteristics of Mississippi River water at Chain of Rocks Plant in St. Louis, Mo., 1969-70.*

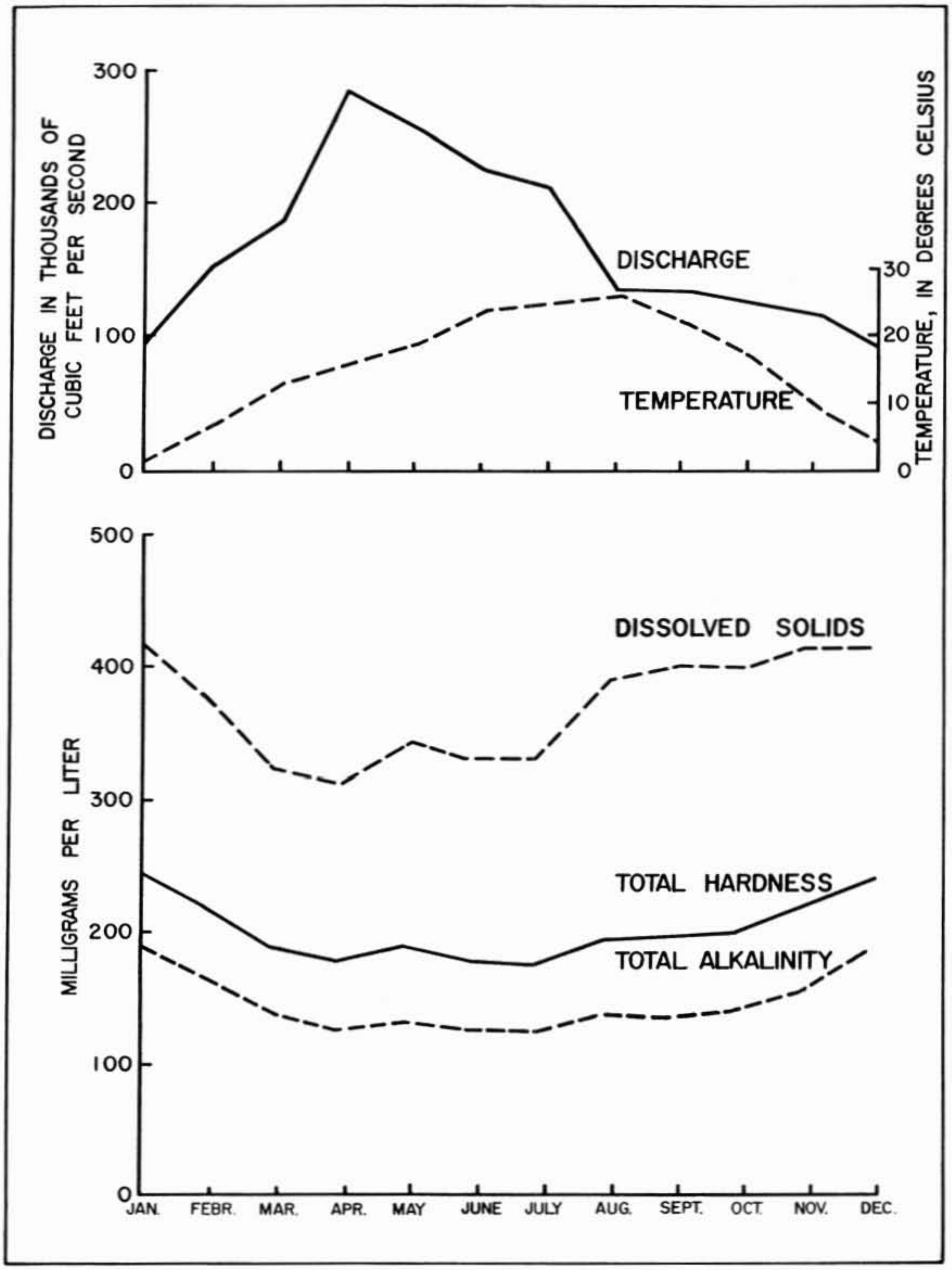



Figure 34

*Average monthly chemical and physical characteristics of the Mississippi River water at Chain of Rocks Plant in St. Louis, Mo., 1951-70.*

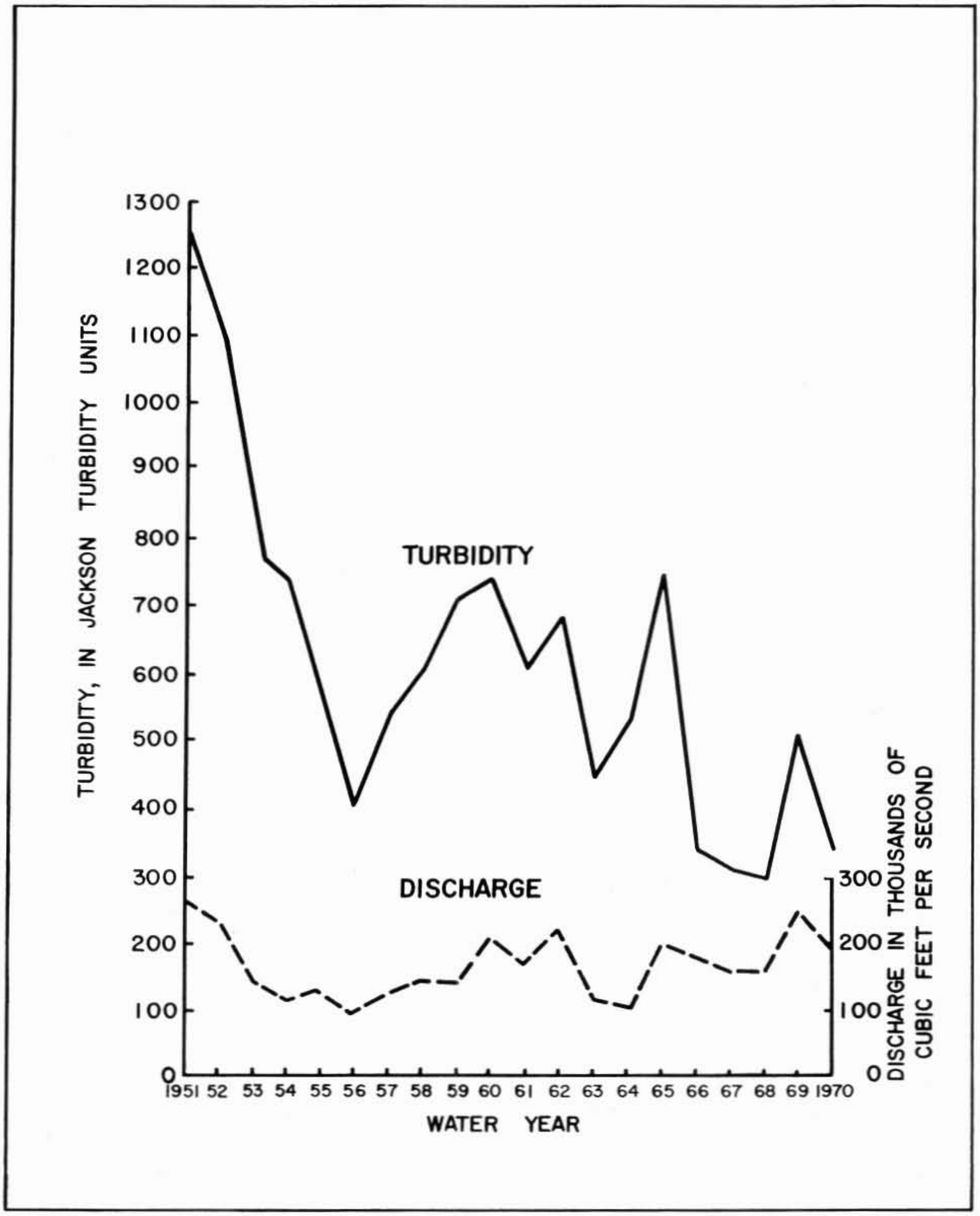



Figure 35

*Annual average turbidity and discharge of the Mississippi River at Chain of Rocks Plant in St. Louis, Mo., 1951-70.*

TRIBUTARY STREAMS

Streams tributary to the Missouri and Mississippi Rivers in the St. Louis area represent a small part of the total volume of surface water available to that area. However, distribution of the smaller streams throughout the three counties makes them important.

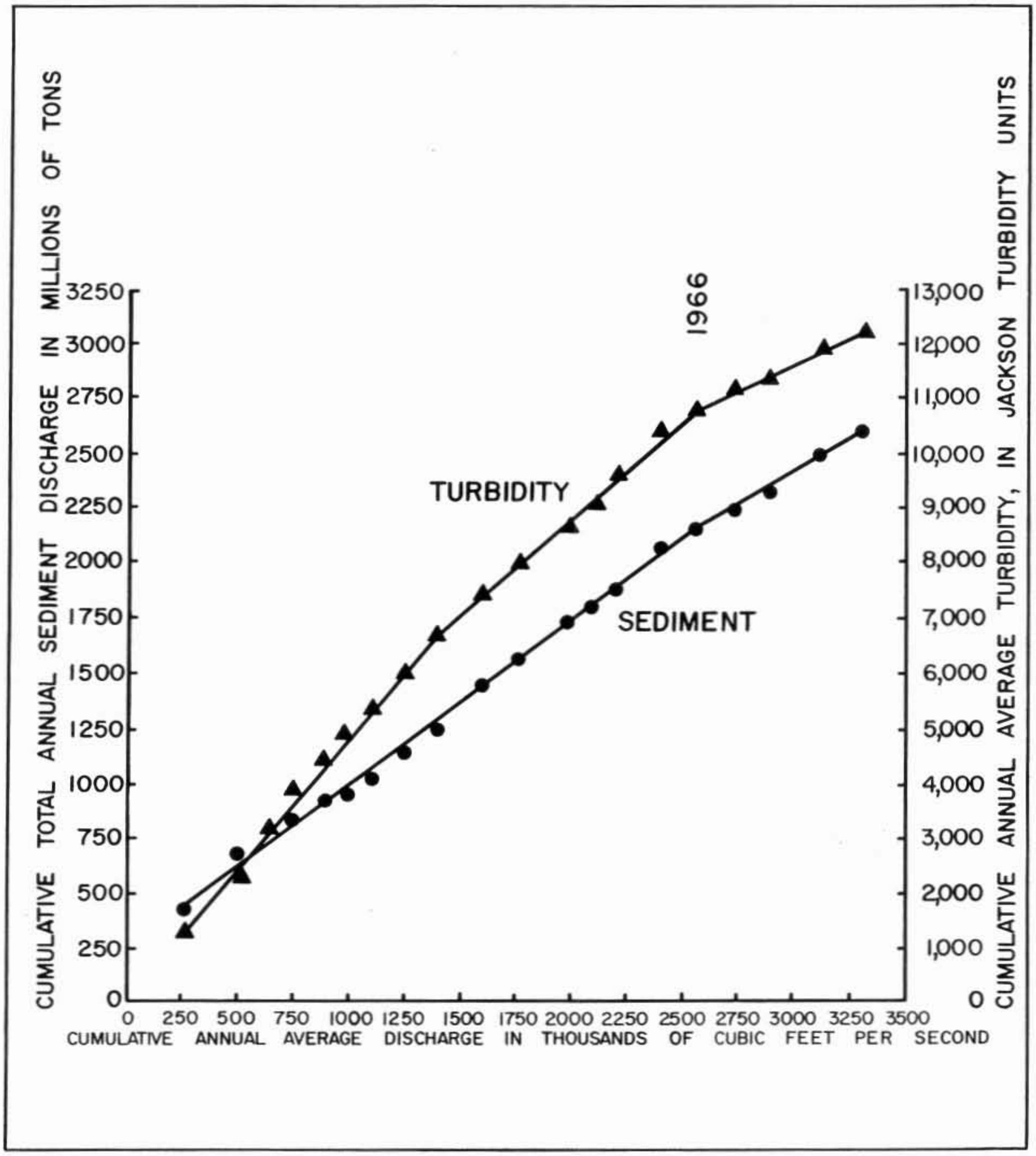



Figure 36

*Double-mass curve of turbidity and sediment versus discharge for the Mississippi River at Chain of Rocks Plant in St. Louis, Mo., 1951-70.*

The largest of the tributary streams are the Meramec River and the Big River, which flows into the Meramec.

The U.S. Geological Survey has a monthly sampling station at the gaging station on the Big River near De Soto, Mo. (fig. 2, map no. 42). Data covering some of the more important water-quality characteristics for the period 1966-70 are summarized in table 26. Water in the Big River is a calcium-magnesium-bicarbonate type.

Fecal coliform bacteria counts for the Big River ranged from 1 to 13,000 col/100 ml, with a median of about 70 for the monthly samples collected during the 1970 water year. Fecal streptococci varied from 12 to 45,000, with a median of about 140 col/100 ml. Fecal coliform to fecal streptococci ratios for individual samples averaged about 0.5, indicating that the pollution was derived predominantly from animal wastes.

The Meramec River flows into the Mississippi River south of St. Louis, about 34 miles downstream from the mouth of the Missouri River. Records of discharge are given for the gaging station at Eureka, Mo., about 35 miles upstream from the mouth (fig. 2, map no. 52).

Suspended-sediment discharges for the Meramec River at Eureka, Mo., from February 1969 to September 1970, ranged from 17 to 175,000 tons per day and averaged 2,680 tons per day. Daily sediment concentrations varied from 19 to 1,430 mg/l and averaged 147 mg/l. Sediment loads and concentrations were affected at times during the period by highway construction activities upstream from the sampling site. The stream is normally clear and transports relatively small amounts of sediment. Most of the sediment discharge occurs during short periods of high streamflow.

The St. Louis County Water Company furnished data for the Meramec River at Fenton, Mo., about 16 miles upstream from the mouth (fig. 2, map no. 59). Some of the characteristics for daily samples collected during the period 1966-70 are summarized in table 27. The average hardness of 166 mg/l indicates that the water is hard. Turbidity is normally low in the Meramec River and not a problem for most uses. Monthly variations are shown in figure 37. A compilation of annual average values of several of the

Table 26

Selected chemical and physical characteristics of water from the Big River near De Soto, Mo., 1966-70

| Characteristic | Minimum | Median | Maximum |
|---|---|---|---|
| Temperature (°C)---------- | 0 | 14.0 | 28.0 |
| pH----------------------- | 7.4 | 8.1 | 8.5 |
| Alkalinity as $CaCO_3$ (mg/l) | 92 | 211 | 246 |
| Hardness as $CaCO_3$ (mg/l) | 110 | 245 | 296 |
| Dissolved solids (mg/l)--- | 144 | 271 | 342 |
| Turbidity (JTU)---------- | 0 | 6 | 300 |

more important water-quality characteristics of the Meramec River at Fenton, Mo., for the period January 1966 to December 1970, are listed in table 28. Meramec River water is also a calcium-magnesium-bicarbonate type.

The U.S. Geological Survey operates a monthly sampling station on the Meramec River at Paulina Hills, Mo., about 10 miles upstream from the mouth (fig. 2, map no. 61). Dissolved solids, hardness and alkalinity duration curves for the period August 1963 to September 1970 are shown in figure 38. The median value, that which was equaled or exceeded 50 percent of the time, was 208 mg/l for dissolved solids, 176 mg/l as $CaCO_3$ for hardness, and 160 mg/l as $CaCO_3$ for alkalinity.

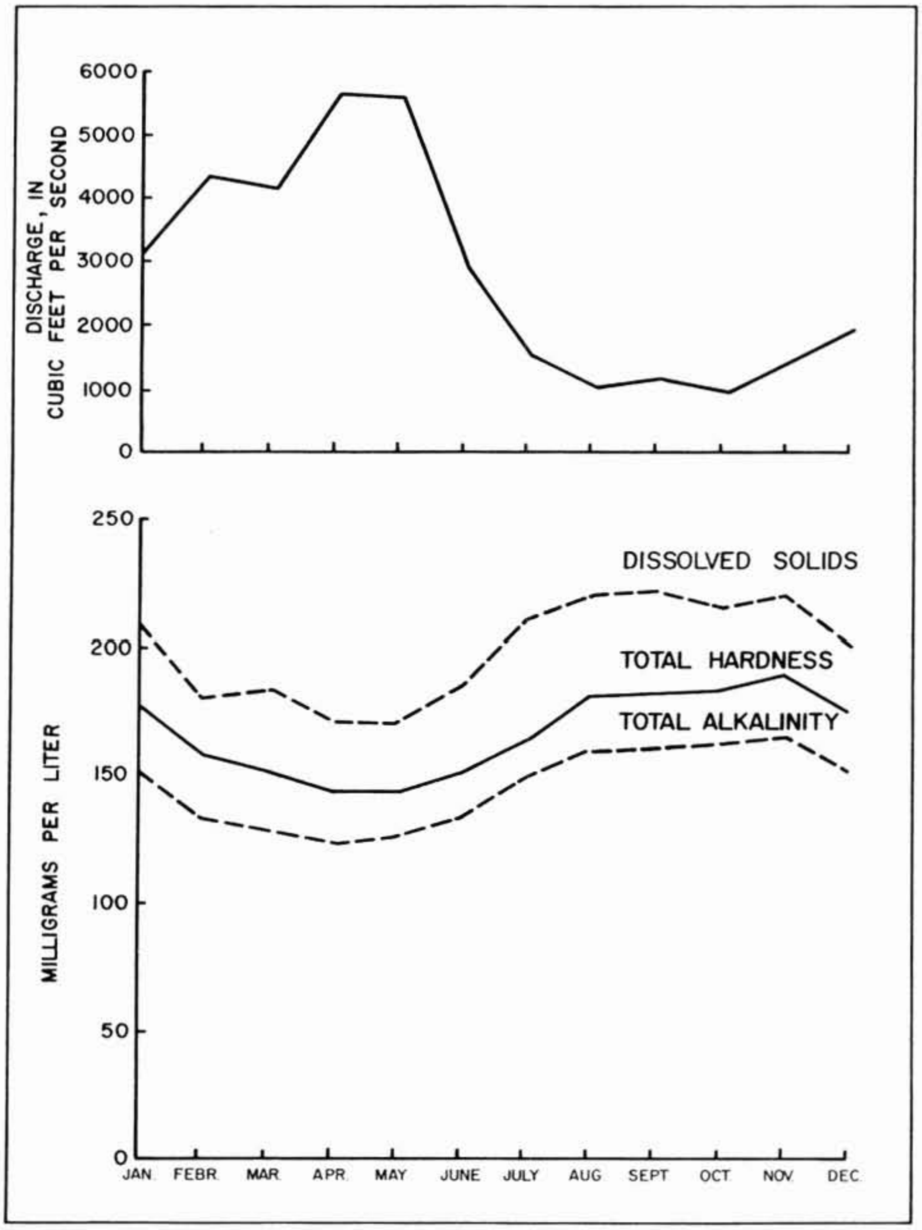



Figure 37

*Average monthly chemical and physical characteristics of the Meramec River at Fenton, Mo., 1966-70.*

Table 27

Selected chemical and physical characteristics of water from the Meramec River at St. Louis County South Plant in Fenton, Mo., 1966-70 [analyses by St. Louis County Water Co.]

| Characteristic | Minimum | Mean | Maximum |
|---|---|---|---|
| pH------------------------ | 7.8 | 8.2 | 8.6 |
| Alkalinity as $CaCO_3$ (mg/l) | 29 | 145 | 210 |
| Hardness as $CaCO_3$ (mg/l) | 36 | 166 | 236 |
| Dissolved solids (mg/l) | 17 | 198 | 428 |
| Turbidity (JTU)----------- | 1 | 64 | 2,000 |

Fecal coliform bacteria counts for the Meramec River varied from 7 to 3,800 col/100 ml and had a median of about 75 for the monthly samples collected in the 1970 water year. Fecal streptococci ranged from 16 to 18,000 and had a median of 55 col/100 ml. Fecal coliform to fecal streptococci ratios for individual samples averaged about 1.1. This indicates that the pollution is mostly derived from animal wastes.

The three-county area is experiencing a high rate of population growth, especially in St. Charles and Jefferson Counties. Much of the development is in unincorporated areas. Because of scattered development, hundreds of individually operated waste-treatment facilities are contributing substantial quantities of treated and partially treated waste effluents to the smaller streams.

Miscellaneous samples were collected from several streams outside the metropolitan St. Louis area, and results of their analysis are in appendix 4. Most of the samples were collected during times of low streamflow.

Table 28

Annual average water-quality characteristics of the Meramec River at Fenton, Mo., 1966-70 [In milligrams per liter except as indicated; analyses by St. Louis County Water Co.]

| Year ending December 31 | 1966 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|
| Silica ($SiO_2$)------------- | 6.8 | 6.4 | 7.4 | 7.4 | 7.0 |
| Iron (Fe)----------------- | 0.04 | 0.07 | 0.06 | 0.02 | 0.01 |
| Calcium (Ca)-------------- | 34 | 32 | 33 | 34 | 34 |
| Magnesium (Mg)------------ | 21 | 19 | 20 | 19 | 19 |
| Sodium and Potassium (Na&K) | 6 | 6 | 5 | 6 | 4 |
| Carbonate ($CO_3$)----------- | 3 | 2 | 2 | 2 | 3 |
| Bicarbonate ($HCO_3$)-------- | 148 | 138 | 140 | 140 | 139 |
| Sulfate ($SO_4$)------------- | 21 | 18 | 20 | 20 | 19 |
| Chloride (Cl)------------- | 11 | 9 | 8 | 9 | 9 |
| Fluoride (F)-------------- | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Nitrate ($NO_3$)------------- | 2.2 | 1.7 | 2.5 | 2.4 | 2.0 |
| Ammonia ($NH_3$)------------- | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Ortho Phosphate ($PO_4$)----- | 0.11 | 0.13 | 0.14 | 0.13 | 0.13 |
| Dissolved solids---------- | 201 | 193 | 195 | 195 | 203 |
| Alkalinity as $CaCO_3$------- | 151 | 140 | 142 | 142 | 142 |
| Hardness as $CaCO_3$--------- | 172 | 159 | 164 | 164 | 165 |
| Color (units)------------- | 10 | 19 | 16 | 15 | 17 |
| Turbidity (JTU)----------- | 40 | 65 | 56 | 60 | 85 |
| pH (units)---------------- | 8.2 | 8.2 | 8.2 | 8.2 | 8.2 |

The surface water in St. Charles County flows over limestone rocks and is a calcium-bicarbonate type. Streams in Jefferson County flow over dolomitic rocks, and the water is a calcium-magnesium-bicarbonate type. The higher magnesium content in Jefferson County is accompanied by a higher hardness than in St. Charles County.

Bacteria counts for small streams in St. Charles County are generally higher than those in Jefferson County and show a higher fecal coliform to fecal streptococci ratio, which indicates that the bacteria are probably from human wastes.

Maline, Gravois, Cold Water and Watkins Creeks, and River des Peres are the principal watersheds in the metropolitan St. Louis area. They include an area of approximately 188 square miles and an estimated 1970 population of 1,009,000 persons. These streams receive residential, commercial and industrial wastes and receive runoff from highly urbanized areas to the point where they cannot assimilate all the wastes. The Metropolitan St. Louis Sewer District (MSD) is currently making a study of the area's water resources problems and needs and will make recommendations for improvement of surface-water quality.

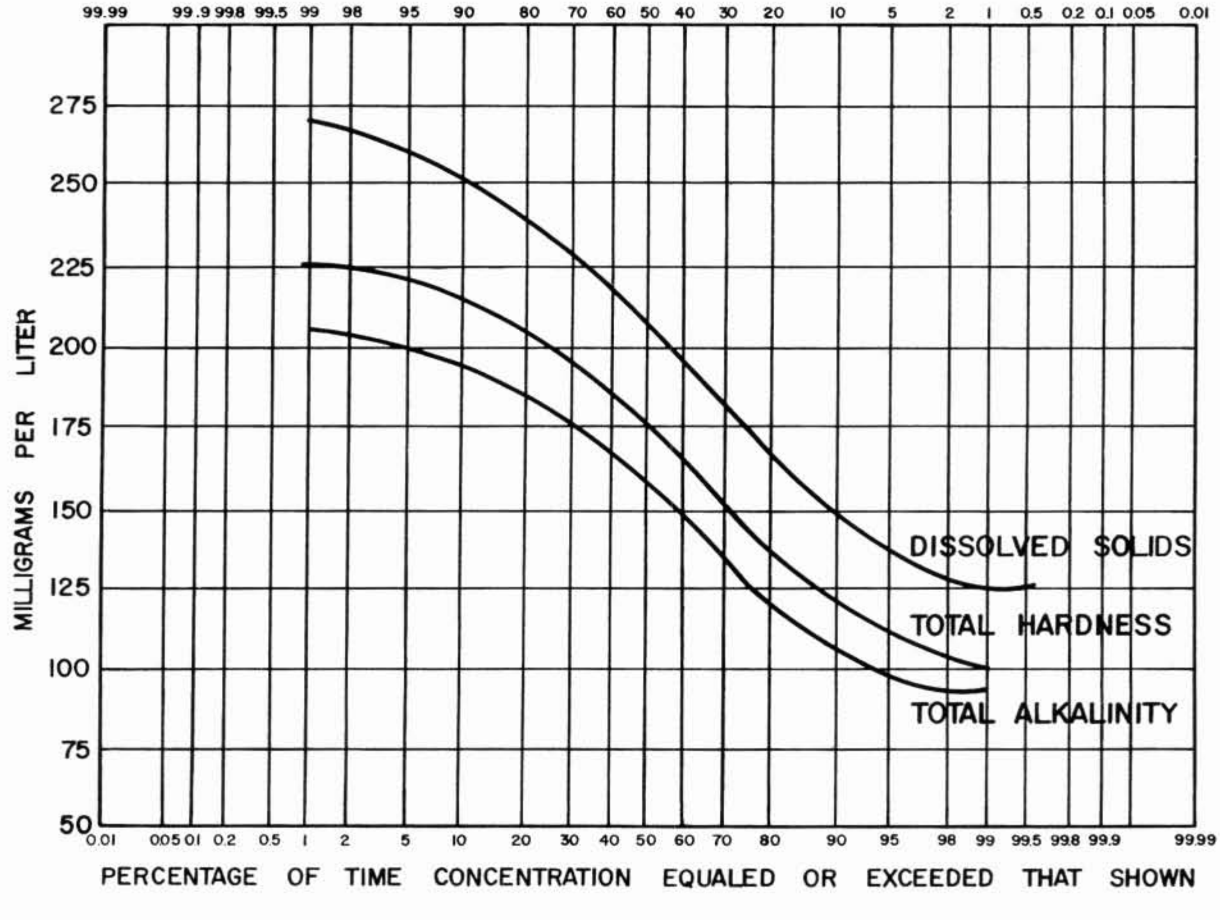



**Figure 38**

*Duration curves of selected water-quality characteristics of the Meramec River at Paulina Hills, Mo.*

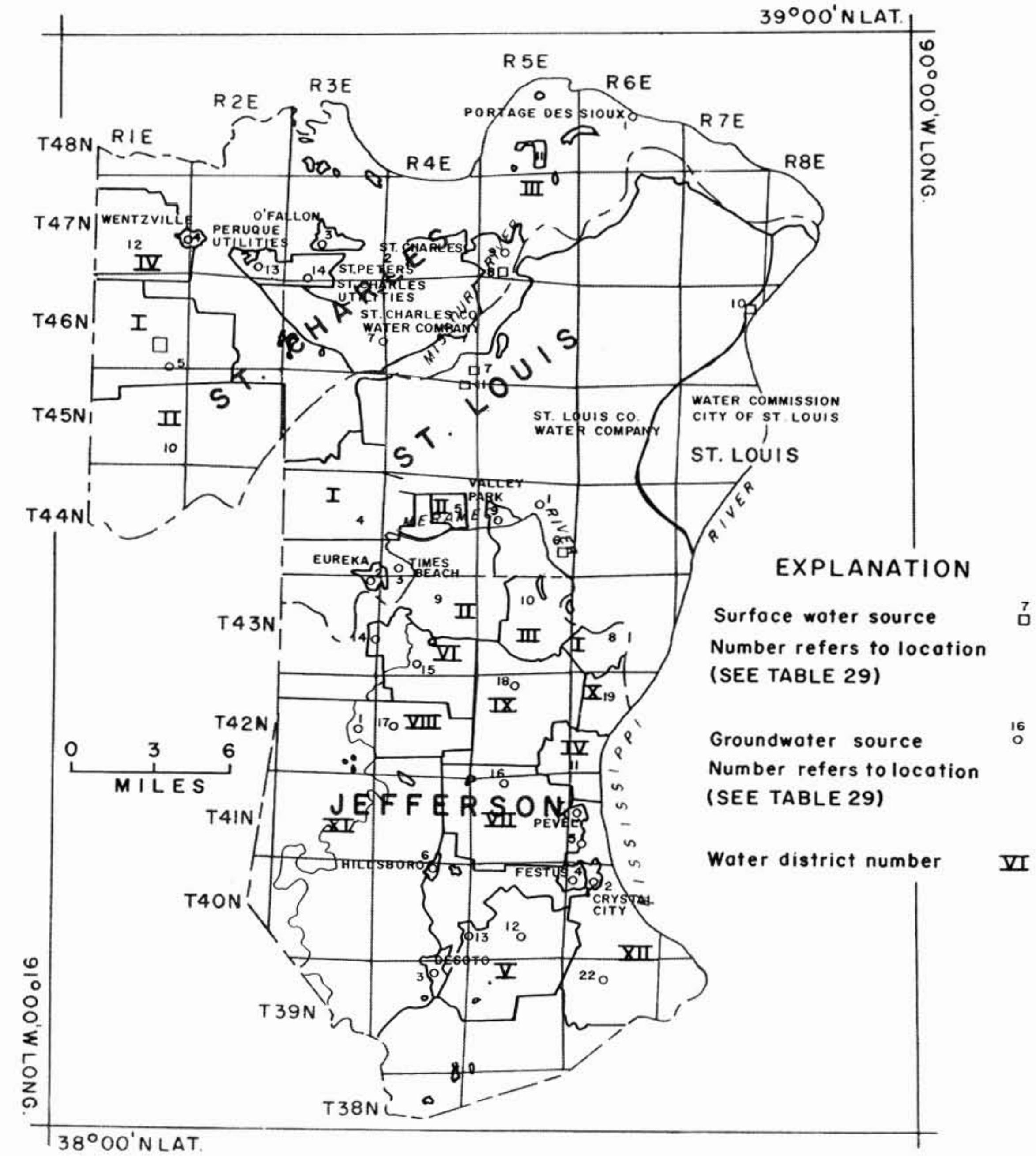



Figure 39

*Areas served by a central water supply. Roman numerals indicate the water district numbers. Modified from East-West Gateway Coordinating Council (Water Facilities Map, 1970).*

## WATER UTILIZATION

The principal uses of water in the three-county area, the estimated amounts used, and the source of the water are shown below:

| Use | Source and amounts (mgd) | |
|---|---|---|
| | Surface water | Ground water |
| Public water supply *, + | 292 | 10 |
| Rural use | 3 | 6 |
| Irrigation | See text | |
| Thermoelectric power * | 819 | — |
| Self-supplied industrial * | 9 | 15 |
| Total | 1,123 | 31 |

* Data from Missouri Water Resources Board, 1970.
Census of Public Water Supplies in Missouri, 1969.

Approximately 97 percent of the water used in the three-county area comes from a surface-water source, 2 percent of the water used is pumped from alluvial aquifers, and 1 percent is pumped from bedrock aquifers. More than 85 percent of the surface water used is from the Mississippi River.

Figures for public supply include water used by municipalities, water-supply districts, subdivisions and trailer courts. Figure 39 and table 29 show the cities and public water-supply districts served by a central water supply. The City of St. Louis and the St. Louis County Water Company account for approximately 289 of the 292 mgd of surface water used for public water supply. Rural use is for both domestic and livestock purposes and was estimated based on census figures. The amount of water used for irrigation will vary with rainfall. In 1968 it was estimated that approximately 60 million gallons per year were used for irrigation of crops. A little over half of this amount was from wells. An undetermined, but probably small amount of water is withdrawn from wells in the Mississippi River alluvium of St. Charles County. Water from these wells is pumped into reservoirs to provide a suitable habitat for waterfowl during the hunting season. By far the largest use of water is for the generation of thermoelectric power. This is largely a nonconsumptive use, the water being used primarily for cooling.

## SUMMARY AND CONCLUSIONS

### SURFACE WATER

No shortage of surface-water supplies is foreseeable for major users who are able to tap the large rivers of the area. Of the large amount of available surface water (114,000 million gallons per day on the average), only about 1,120 million gallons per day is withdrawn for all uses.

Those who are interested in supplies from the smaller tributary streams face more difficult problems. The natural flows of streams in St. Charles and St. Louis Counties and the northern two-thirds of Jefferson County are generally highly variable. In these areas, as shown in figure 26, a lack of natural sustained low flows makes it necessary to utilize storage reservoirs when year-round surface-water supplies are required. Streams in southern Jefferson County have a more consistent flow pattern and better-sustained low flows. However, major water users would probably require storage reservoirs in this region also.

Impoundments may not be necessary to insure adequate quantities of water in the lower reaches of many tributary streams. These reaches are ponded by backwater from the Mississippi and Missouri Rivers, thus maintaining a dependable supply in the channel.

Table 29

Water-Supply Facilities In The St. Louis Area

| Municipality or operating agency | No. on map (Fig. 39) | Source | Average pumpage (million gallons per day) |
|---|---|---|---|
| St. Louis County | | | |
| Kirkwood | 1 | Ranney well: Aux. Meramec River and St. Louis County Water Co. | 3.500 |
| Eureka | 2 | 3 wells | .172 |
| Times Beach | 3 | 1 well | .100 |
| St. Louis County Water District No. 1 | 4 | St. Louis County Water Co. | .041 |
| St. Louis County Water District No. 2 | 5 | St. Louis County Water Co. | .041 |
| St. Louis County Water Co. | | | 100.000 |
| South Plant | 6 | Meramec River | - |
| Central Plant | 7 | Missouri River | - |
| North Plant | 8 | Missouri River | - |
| Valley Park | 9 | 2 wells | .294 |
| City of St. Louis | | | |
| St. Louis City Water Co. | | | 150.000 |
| Chain of Rocks Plant | 10 | Mississippi River | - |
| Howard Bend Plant | 11 | Missouri River | - |
| St. Charles County | | | |
| Portage Des Sioux | 1 | 1 alluvial well | 0.025 |
| St. Peters | 2 | 2 drilled wells | 0.035 |
| O'Fallon | 3 | 3 drilled wells | 0.533 |
| Wentzville | 4 | 4 drilled wells | 0.350 |
| St. Charles PWSD No. 1 | 5 | 1 drilled well | - |
| St. Charles County Water Division | | | |
| North Plant | 6 | 3 alluvial wells | .400 |
| South Plant | 7 | 2 alluvial wells | 0.100 |
| St. Charles City | | | 3.000 |
| Plant No. 1 | 8 | Missouri River | |
| Plant No. 2 | 9 | 5 alluvial wells: Mississippi River Bottom | - |
| St. Charles PWSD No. 2 | 10 | Under construction | - |
| St. Charles PWSD No. 3 | 11 | Dormant | - |
| St. Charles PWSD No. 4 | 12 | Dormant | - |
| Peruque Utilities | 13 | 2 wells | - |
| St. Charles Utilities | 14 | 1 well | - |

Water-Supply Facilities In The St. Louis Area--continued

| Municipality or operating agency | No. on map (Fig. 39) | Source | Average pumpage (million gallons per day) |
|---|---|---|---|
| Jefferson County | | | |
| Cedar Hill | 1 | 2 wells | .043 |
| Crystal City | 2 | Ranney well | .500 |
| De Soto | 3 | 2 wells | .650 |
| Festus | 4 | 5 wells | .500 |
| Herculaneum | 5 | 3 wells | .280 |
| Hillsboro | 6 | 3 wells | .130 |
| Pevely | 7 | 2 wells | .058 |
| Jefferson County PWSD No. 1 | 8 | St. Louis County Water Co. | .750 |
| Jefferson County PWSD No. 2 | 9 | St. Louis County Water Co. | .173 |
| Jefferson County PWSD No. 3 | 10 | St. Louis County Water Co. | .200 |
| Jefferson County PWSD No. 4 | 11 | Jefferson County PWSD No. 9 | - |
| Jefferson County PWSD No. 5, East | 12 | 1 well | .031 |
| Jefferson County PWSD No. 5, West | 13 | 1 well | .024 |
| Jefferson County PWSD No. 6 (Hoene Springs) | 14 | 2 wells | .010 |
| Jefferson County PWSD No. 6 (House Springs) | 15 | 1 well | .040 |
| Jefferson County PWSD No. 7 | 16 | 2 wells | .055 |
| Jefferson County PWSD No. 8 | 17 | 1 well | .024 |
| Jefferson County PWSD No. 9 | 18 | 2 wells | .070 |
| Jefferson County PWSD No. 10 | 19 | St. Louis County Water Co. | - |
| Jefferson County PWSD No. 12 | 20 | 1 well | - |

Modified from East-West Gateway Coordinating Council (Water Facilities Inventory and Evaluation, 1971).

However, extensive treatment may be required to make the water suitable for use.

When developments are planned in the tributary basins, proposed effluent loads should always be balanced against streamflow available for dilution. The low-flow potential of the stream is the principal limiting factor in effective waste disposal via the drainage network and can be evaluated by using the analysis and tabulations presented in the "Low Flows" section of this report.

The low flows of many small tributary streams are already greatly augmented by domestic effluent, with a net increase in dry-weather flow. From a water-use standpoint, augmentation of small natural streamflows by this effluent is not desirable because of high treatment costs.

The increase of low flows by urbanization has been accompanied by an increase in average annual runoff and flood peaks. The intensity of these effects depends on the percentage of impervious area in a basin and the quantity of effluent entering the stream from sewage treatment plants, septic tanks, industry and storm sewers. During low-order floods (2-year recurrence interval), storm sewers, gutters and man-made ditches greatly increase peak flows over those that occur in comparable rural areas. During greater flood events, they function less efficiently, and the difference between urban and rural flood peaks becomes smaller. The 25-year flood for a

60-percent urbanized basin in St. Louis County with an estimated 20-percent impervious area is about 2.5 times greater than the 2-year flood, whereas the same flood from a rural basin in the area is about 3.5 times greater than the 2-year flood. The average annual runoff for the same urbanized basin is about twice that of a comparable rural stream.

Flood problems will probably become more severe on tributary streams in the area as industrial and domestic development increase on the floodplains. The time distribution of floods will remain the same, barring major climatic changes, with most floods occurring in the 5-month period, March through July.

Springs in the study area are of little economic value because of their small and highly variable discharge. Some of the springs and seeps are becoming increasingly polluted as urbanization spreads, further limiting their value as a water supply.

The predominant chemical constituents of water in the Missouri River near St. Louis are calcium, magnesium, sodium, bicarbonate and sulfate. Variations in dissolved-solids content are primarily caused by variations in the amounts of these constituents. The water is hard and turbidity is relatively high. However, impoundments on the Missouri River main stem and tributaries over the past 20 years have resulted in a significant decrease in turbidity.

Water in the Mississippi River upstream from the mouth of the Missouri River is a calcium-bicarbonate type and contains significant amounts of magnesium and sulfate in the dissolved solids. Turbidity upstream from the Missouri River is relatively low and the water is very hard.

Water from the Meramec River is a $CaCO_3$ type. The water is hard, and turbidity is normally low.

Water from tributary streams in St. Charles County is primarily a calcium-bicarbonate type. Water from streams in Jefferson County contains significant amounts of magnesium in addition to calcium and bicarbonate. Fecal coliform to fecal streptococci bacteria ratios were higher in St. Charles County than in Jefferson County, indicating more contamination by human wastes.

The influence of urbanization on water quality of small streams is characterized by the generally deteriorated condition of the streams in St. Louis County, particularly those in the metropolitan St. Louis area.

## GROUND WATER

Alluvial aquifers having the greatest potential for development are those underlying the floodplains of the Mississippi and Missouri Rivers. Wells capable of yielding more than 2,000 gpm can be constructed in much of this area. Larger sustained yields could be obtained by locating the wells so that infiltration would be induced from the river.

Wells capable of yielding 500 to 1,500 gpm can be developed at carefully selected sites in the alluvium bordering the Meramec River. Yields exceeding 500 gpm from wells in the Meramec River alluvium probably would require the installation of a well or wells capable of inducing infiltration from the river.

Little is known about the aquifer characteristics of the alluvium bordering the smaller perennial streams in the area, but it is doubtful whether a suitable supply could be developed unless a water-supply facility capable of inducing recharge from the stream could be installed. This installation would probably have to be an infiltration gallery or radial collector well.

Water from the Mississippi, Missouri and Meramec River alluvium generally is a calcium-magnesium-bicarbonate type. The water is very hard and contains significant quantities of iron and manganese. Locally, in the Meramec River alluvium such as at Valley Park and Times Beach, some wells yield a sodium-chloride type of water.

Wells yielding more than 50 gpm of potable water can be developed from the bedrock aquifers in the western third of St. Charles County, the extreme western part of St. Louis County, and the southwestern three-fourths of Jefferson County. The most important bedrock aquifers in the area are the Potosi Dolomite (5), Gasconade Dolomite (4), Roubidoux Formation (4) and St. Peter Sandstone (3).

## SELECTED REFERENCES


**Anderson, D.G.**, 1970, Effects of urban development on floods in northern Virginia: U.S. Geol. Survey, Water-Supply Paper 2001-C, p. C1-C22.

**Benson, M.A.**, 1962, Factors influencing the occurrence of floods in a humid region of diverse terrain: U.S. Geol. Survey, Water-Supply Paper 1580-B, 64 p.

________1964, Factors affecting the occurrence of floods in the Southwest: U.S. Geol. Survey, Water-Supply Paper 1580-D, 70 p.

**Bergstrom, R.E.** and **T.R. Walker**, 1956, Groundwater geology of the East St. Louis area, Illinois: Ill. Geol. Survey, Rept. Inv. 191, 44 p.

**Carter, R.W.**, 1961, Magnitude and frequency of floods in suburban areas, in Short papers in the geologic and hydrologic sciences: U.S. Geol. Survey, Prof. Paper 424-B, p. B9-B11.

**Cole, V.B.**, 1961, The Cap au Gres Fault in Northeastern Missouri and west-central Illinois, Kansas Geol. Society 26th Ann. Field Conf. Guidebook: Mo. Geol. Survey and Water Resources, Rept. Inv. 27, p. 86-88, 1 fig.

**Collinson, C.W., D.H. Swann** and **H.B. Willman**, 1954, Guide to structure and Paleozoic stratigraphy along the Lincoln Fold in western Illinois: Ill. Geol. Survey, Guidebook, 39th Annual Convention, Am. Assoc. Petroleum Geologists, St. Louis Meeting.

**Comly, H.H.**, 1945, Cyanosis in infants caused by nitrate in well water: Am. Medical Assoc. Jour., v. 129, p. 112-116.

**Crippen, J.R.**, and **A.O. Waananen**, 1969, Hydrologic effects of suburban development near Palo Alto, California: U.S. Geol. Survey, open-file rept., 126 p.

**Dean, H.T.**, 1936, Chronic endemic fluorosis: Am. Medical Assoc. Jour., v. 107, p. 1269-1272.

**East-West Gateway Coordinating Council**, 1970, Water facilities map of the St. Louis metropolitan area: East-West Gateway Coordinating Council.

**Emmett, L.F.**, and **H.G. Jeffery**, 1968, Reconnaissance of the groundwater resources of the Missouri River alluvium between St. Charles and Jefferson City, Missouri: U.S. Geol. Survey, Hydrol. Inv. Atlas HA-315.

**Englemann, George**, 1847, Carboniferous rocks of St. Louis and vicinity: Am. Jour. Sci., 2d ser., v. 3, p. 119-120.

**Espey, W.H., C.W. Morgan** and **F.D. Masch**, 1966. a study of some effects of urbanization on storm runoff from a small watershed: Texas Water Development Board, Rept. 23, 109 p.

**Fenneman, N.M.**, 1911, Geology and mineral resources of the St. Louis quadrangle, Missouri-Illinois: U.S. Geol. Survey, Bull. 438, 73 p.

________1946, Physical divisions of the United States: U.S. Geol. Survey Physiographic Committee Map.

**Gann, E.E.**, 1971, Generalized flood-frequency estimates for urban areas in Missouri: U.S. Geol. Survey, open-file rept., 18 p.

**Gann, E.E., E.J. Harvey, H.G. Jeffery** and **D.L. Fuller**, 1971, Water resources of northeastern Missouri: U.S. Geol. Survey, Hydrol. Inv. Atlas HA-372.

**Gleason, C.D.**, 1935, Underground water in St. Louis County and City of St. Louis, Missouri: Geol. Survey and Water Resources, Bienn. Rept. 1933-34, app. 5, p. 24, 5 pls., 1 fig.

**Gringorten, I.I.**, 1963, A plotting rule for extreme probability paper: Jour. Geophys. Research, v. 68, n. 3, p. 813-814.

**Grohskopf, J.G.**, 1948, Zones of Plattin-Joachim of eastern Missouri: Mo. Geol. Survey and Water Resources, Rept. Inv. 6, p. 15, 5 figs.

**Grohskopf, J.G.**, and **Earl McCracken**, 1949, Insoluble residues of some Paleozoic formations of Missouri; their preparation, characteristics, and application: Geol. Survey and Water Resources, Rept. Inv. 10, p. 39, 11 pls.

**Harris, E.E.**, and **S.E. Rantz**, 1964, Effect of urban growth on streamflow regimen of Permanente Creek, Santa Clara County, California: U.S. Geol. Survey, Water-Supply Paper 1591-B, 18 p.

**Hauth, L.D.**, and **D.W. Spencer**, 1969, Floods in Gravois Creek basin, St. Louis County, Missouri: U.S. Geol. Survey, open-file rept., 14 p.

________1971, Floods in Coldwater Creek, Watkins Creek, and River Des Peres basins, St. Louis County, Missouri: U.S. Geol. Survey, open-file rept., 36 p.

**Hem, John D.**, 1970, Study and interpretation of the chemical characteristics of natural water (2nd ed.): U.S. Geological Survey, Water-Supply Paper 1473.

**James, L. Douglas**, 1965, Using a digital computer to estimate the effects of urban development on flood peaks: Water Resources Research, v. 1, n. 2, p. 233-234.

**Jordan, P.R.**, 1965, Fluvial sediment of the Mississippi River at St. Louis, Missouri: U.S. Geol. Survey, Water-Supply Paper 1802, 89 p.

__________1968, Summary and analysis of sediment records, in relation to St. Louis harbor sedimentation problem: U.S. Geol. Survey, open-file rept., 30 p.

**Kissling, D.L.**, 1960, Lower Osagean stratigraphy of east-central Missouri and adjacent Illinois: Unpubl. Master's thesis, Wisconsin U., p. 125, illus.

**Larson, D.R.**, 1951, Stratigraphy of the Plattin Group, southeastern Missouri: Am. Assoc. Petroleum Geol. Bull., v. 35, n. 9, p. 2041-2075, 16 figs.

**Lohman, S.W.**, 1972, Definitions of selected groundwater terms: U.S. Geol. Survey, Water-Supply Paper 1988.

**Lutzen, E.E.**, 1968, Engineering geology of the Maxville quadrangle, Jefferson and St. Louis Counties, Missouri: Mo. Geol. Survey and Water Resources, Engr. Geol. ser. 1.

**McCracken, Earl**, and **M.H. McCracken**, 1965, Subsurface maps of the Lower Ordovician (Canadian Series) of Missouri: Mo. Geol. Survey and Water Resources.

**McCracken, M.H.**, 1966, The structural features of St. Louis County and vicinity, in Middle Ordovician and Mississippian strata, St. Louis and St. Charles Counties, Missouri: Mo. Geol. Survey and Water Resources, Rept. Inv. 34, p. 38-41.

**McQueen, H.S.**, 1939, Guide to field study between Cape Girardeau and St. Louis, Missouri in Guidebook, Thirteenth Annual Field Conference of the Kansas Geological Society in southwestern Illinois and southeastern Missouri: Kan. Geol. Society, p. 93.

**Marbut, Curtis F.**, 1896, Surface features of Missouri: Mo. Geol. Survey, v. X, p. 533.

**Mehl, M.G.**, 1960, The relationships of the base of the Mississippian System in Missouri: Jour. Scientific Laboratories, Denison U., v. 45, art. 5, p. 57-107, 8 figs.

**Meinzer, O.E.**, 1923, The occurrence of ground water in the United States, with a discussion of principles: U.S. Geol. Survey, Water-Supply Paper 489, p. 321.

**Owens, W.G.**, 1960, Occurrence of mineralized ground water in southern St. Louis and Jefferson Counties, Missouri: Unpubl. Master's thesis, Missouri U. at Rolla, p. 99.

**Peterson, M.S.**, 1965, Floods of June 17th and 18th, 1964, in Jefferson, Ste. Genevieve, and St. Francois Counties, Missouri: Mo. Geol. Survey and Water Resources, Water Resources Rept. 19, 20 p.

**Rorabaugh, M.I.**, 1963, Streambed percolation in development of water supplies in Bentall, Ray, 1963, Methods of collecting and interpreting groundwater data: U.S. Geol. Survey, Water-Supply Paper 1544-H, p. 47-62.

**Schicht, R.J.**, 1965, Groundwater development in East St. Louis area, Illinois: Ill. Water Survey, Rept. Inv. 51, 70 p.

**Scott, C.H.**, and **H.D. Stephens**, 1966, Special sediment investigations, Mississippi River at St. Louis, Missouri, 1961-63: U.S. Geol. Survey, Water-Supply Paper 1819-J, 35 p.

**Searcy, J.K.**, **R.C. Baker** and **W.H. Durum**, 1952, Water resources of the St. Louis area, Missouri and Illinois: U.S. Geol. Survey, Circ. 216, 55 p.

**Searcy, J.K.**, and **C.H. Hardison**, 1960, Double-mass curves: U.S. Geol. Survey, Water-Supply Paper 1541-B, 66 p.

**Searight, W.V.**, 1958, Pennsylvanian (Desmoinesian) of Missouri: Mo. Geol. Survey and Water Resources, Rept. Inv. 25, p. 46, 2 pls, 30 figs.

**Searight, W.V.**, and **T.K. Searight**, 1961, Pennsylvanian geology of the Lincoln Fold in Guidebook, Twenty-sixth Regional Field Conference, Kansas Geological Society: Mo. Geol. Survey and Water Resources, Rept. Inv. 27, p. 156-163, 2 figs.

**Sheaffer, J.R.**, and **A.J. Zeizel**, 1966, The water resources in northeastern Illinois - planning its use: Northeastern Ill. Planning Comm., Tech. Rept. 4, 182 p.

**Skelton, John,** 1966, Low-flow characteristics of Missouri streams: Mo. Geol. Survey and Water Resources, Water Resources Rept. 20, 95 p.

_________1968, Storage requirements to augment low flow of Missouri streams: Mo. Geol. Survey and Water Resources, Water Resources Rept. 22, 78 p.

_________1970, Base-flow recession characteristics and seasonal low-flow frequency characteristics for Missouri streams: Mo. Geol. Survey and Water Resources, Water Resources Rept. 25, 43 p.

_________1971, Carryover storage requirements for reservoir design in Missouri: Mo. Geol. Survey and Water Resources, Water Resources Rept. 27, 56 p.

**Skelton, John** and **Anthony Homyk,** 1970, A proposed streamflow data program for Missouri: U.S. Geol. Survey, open-file rept., 44 p.

**Spencer, D.W.,** and **L.D. Hauth,** 1968, Floods in Maline Creek basin, St. Louis County, Missouri: U.S. Geol. Survey, open-file rept., 12 p.

**Spencer, D.W.,** 1971, Computed flood profile, River Des Peres, Groby Street to 82nd Boulevard, University City, St. Louis County, Missouri: U.S. Geol. Survey, open-file rept., 14 p.

**Spieker, A.M.,** 1970, Water in urban planning, Salt Creek basin, Illinois–Water management as related to alternative land-use practices: U.S. Geol. Survey, Water-Supply Paper 2002, 147 p.

**Spreng, A.C.,** 1961, Mississippian System in the stratigraphic succession in Missouri: Mo. Geol. Survey and Water Resources, v. 40, p. 49-78, illus.

**Stiff, H.A.,** 1951, The interpretation of chemical water analysis by means of patterns: Jour. Petroleum Technology, October, sec. 1, p. 15-16, sec. 2, p. 3.

**Stinchcomb, B.L.,** and **L.D. Fellows,** 1968, Geology of the Maxville quadrangle, Jefferson and St. Louis Counties, Missouri: Mo. Geol. Survey and Water Resources, Geol. Quad. Map Ser. 2.

**Stout, L.N.,** 1969, Index to Missouri areal geologic maps 1890-1969: Mo. Geol. Survey and Water Resources, Inf. Circ. 22, 67 p.

**Trapp, Henry,** 1961, Quality of ground water in Jefferson County, Missouri: Unpubl. ms., Mo. Geol. Survey and Water Resources files.

**Tucker, Thomas G.,** 1970, Alternative patterns for growth - the St. Louis region: East-West Gateway Coordinating Council, 42 p.

**U.S. Army Corps of Engineers,** 1957, Suspended sediment in the Missouri River, daily record for water years 1949-1954: Mo. River Div., 210 p.

_________1964a, Floodplain information study, Glaize Creek, Jefferson County, Missouri: U.S. Army Engineers, St. Louis Dist., 10 p., 1 pl.

_________1964b, Floodplain information study, Joachim Creek, Jefferson County, Missouri: U.S. Army Engineers, St. Louis Dist., 10 p., 1 pl.

_________1964c, Floodplain information study, Mississippi River, Jefferson County, Missouri: U.S. Army Engineers, St. Louis Dist., 6 p., 1 pl.

_________1964d, Floodplain information study, Plattin Creek, Jefferson County, Missouri: U.S. Army Engineers, St. Louis Dist., 10 p., 1 pl.

_________1964e, Floodplain information study, Rock Creek, Jefferson County, Missouri: U.S. Army Engineers, St. Louis Dist., 10 p., 1 pl.

_________1964f, Floodplain information study, Sandy Creek, Jefferson County, Missouri: U.S. Army Engineers, St. Louis Dist., 10 p., 1 pl.

_________1965a, Floodplain information study, Big River, Jefferson County, Missouri: U.S. Army Engineers, St. Louis Dist., 10 p., 1 pl.

_________1965b, Floodplain information study, Meramec River, Jefferson County, Missouri: U.S. Army Engineers, St. Louis Dist., 10 p., 2 pl.

_________1965c, Suspended sediment in the Missouri River, daily record for water years 1955-1959: Mo. River Div., 188 p.

_________1966a, Floodplain information study, Dry Creek, Jefferson County, Missouri: U.S. Army Engineers, St. Louis Dist., 9 p., 2 pl.

_________1966b, Floodplain information study, Heads Creek and Bourne Creek, Jefferson County, Missouri: U.S. Army Engineers, St. Louis Dist., 12 p., 3 pl.

_________1966c, Floodplain information study, Saline Creek, Jefferson County, Missouri: U.S. Army Engineers, St. Louis Dist., 12 p., 2 pl.

_________1968, Floodplain information study, Meramec River, Brush Creek, and Fox Creek, Pacific, Missouri: U.S. Army Engineers, St. Louis Dist., 56 p., 25 pl.

_________1970, Suspended sediment in the Missouri River, daily record for water years 1960-1964: Mo. River Div., 190 p.

**U.S. Geological Survey** and **Missouri Division of Geological Survey and Water Resources,** 1967, Mineral and water resources of Missouri: U.S. Sen. Doc. 19, U.S. Gov't. Printing Off., 399 p.

**U.S. Public Health Service,** 1962, Drinking water standards: U.S. Public Health Svc., Pub. 956, p. 61.

**U.S. Water Resources Council,** 1967, A uniform technique for determining flood flow frequencies: U.S. Water Resources Council Bull. 15, 15 p.

**U.S. Weather Bureau,** 1961, Rainfall frequency atlas of the United States: U.S. Weather Bureau, Tech. Paper 40, 115 p.

**Waananen, A.O.,** 1961, Hydrologic effects of urban growth – some characteristics of urban runoff: Art. 275 in U.S. Geol. Survey, Prof. Paper 424-C, p. C353-C356.

**Walton, W.C.,** 1970, Groundwater resource evaluation: McGraw-Hill, N.Y., 664 p.

**Weller, Stuart,** 1908, The Salem limestone in Year-book for 1907: Ill. Geol. Survey, Bull. 8, p. 81-102.

**Weller, J.M.,** and **A.H. Bell,** 1937, Illinois Basin: Am. Assoc. Petrol. Geol. Bull., v. 21, p. 771-788.

**Wiitala, S.W.,** 1961, Some aspects of the effect of urban and suburban development upon runoff: U.S. Geol. Survey, open-file rept., 28 p.

**Willman, H.B.,** and **J.C. Frye,** 1958, Problems of Pleistocene geology in the greater St. Louis area [Mo.-Ill.] in Geol. Soc. Am. field trip guidebook, field trip no. 2, St. Louis Meeting, p. 9-19.

**Wilson, K.V.,** 1966, Flood frequency of streams in Jackson, Mississippi: U.S. Geol. Survey, open-file rept., 6 p.

# APPENDIX 1

# GEOLOGIC LOGS OF SELECTED TEST HOLES IN ALLUVIUM

## *MERAMEC RIVER ALLUVIUM*

### JEFFERSON COUNTY

| 43 - 5 - 13 cbb<br>Surface altitude: about 398 ft.<br>Depth to water, 15 ft., June 12, 1968 | Thickness (feet) | Depth (feet) |
|---|---|---|
| Clay, silty, dark brown | 7 | 7 |
| Clay, silty, sandy, brown | 5 | 12 |
| Clay, silty, sandy; contains some gravel | 15 | 27 |
| Gravel and sand, medium to coarse | 10 | 37 |
| Gravel and sand, silty, brown; contains a few boulders | 41 | 78 |
| Bedrock | – | 78 |

### ST. LOUIS COUNTY

| 43 - 4 - 5bdd<br>Surface altitude: about 430 ft.<br>Depth to water, 30 ft., June 6, 1968 | Thickness (feet) | Depth (feet) |
|---|---|---|
| Silt, sandy, brown | 2 | 2 |
| Clay, silty, sandy, brown | 10 | 12 |
| Clay, sandy; contains trace of gravel | 10 | 22 |
| Sand, fine to medium, clayey, light brown | 5 | 27 |
| Sand, medium, silty, clayey, brown; contains some gravel | 10 | 37 |
| Sand, medium to coarse, silty, clayey; contains some gravel | 20 | 57 |
| Sand, coarse to very coarse; contains much gravel | 4 | 61 |
| Bedrock | – | 61 |

| 43 - 3 - 4cdc<br>Surface altitude: about 455 ft.<br>Depth to water, 8 ft., June 5, 1968 | Thickness (feet) | Depth (feet) |
|---|---|---|
| Clay, dark gray | 2 | 2 |
| Clay, sandy, light brown to gray; contains some gravel | 15 | 17 |
| Sand, very fine to fine, clayey, tan to gray | 10 | 27 |
| Sand, fine to medium, gray | 10 | 37 |
| Sand, very fine to fine, gray to gray-brown; contains some gravel | 20 | 57 |
| Sand, medium; contains some gravel | 3 | 60 |
| Bedrock | – | 60 |

| 44 - 5 - 23bbb<br>Surface altitude: about 410 ft.<br>Depth to water, 24 ft., Jan. 14, 1969 | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, fine to medium, silty, tan | 12 | 12 |
| Sand, medium, silty, brown; contains some gravel | 10 | 22 |
| Sand, medium to coarse, brown; contains some gravel | 10 | 32 |
| Sand, medium to very coarse, silty, brown; contains gravel | 25 | 57 |
| Bedrock | – | 57 |

| 44 - 5 - 35bba<br>Surface altitude: about 410 ft.<br>Depth to water, 17 ft., June 4, 1968 | Thickness (feet) | Depth (feet) |
|---|---|---|
| Clay, silty, dark brown | 2 | 2 |
| Clay, sandy, silty, dark brown | 5 | 7 |
| Sand, medium, clayey, brown | 5 | 12 |
| Sand, medium, silty, brown; contains gravel | 5 | 17 |
| Sand, fine to medium, clayey; contains gravel | 5 | 22 |
| Sand, medium, clayey; contains gravel | 10 | 32 |
| Sand, medium to coarse, clayey; contains much gravel | 26 | 58 |
| Bedrock | – | 58 |

| 44 - 3 - 24dad<br>Surface altitude: about 430 ft.<br>Depth to water, 28 ft., June 7, 1968 | Thickness (feet) | Depth (feet) |
|---|---|---|
| Silt, clayey, brown | 2 | 2 |
| Clay, silty, sandy, brown | 10 | 12 |
| Sand, very fine to fine, silty, brown | 30 | 42 |
| Sand, fine to medium, silty, brown; contains some gravel | 10 | 52 |
| Sand, medium, some fine, silty, clayey, brown; contains some gravel | 19 | 71 |
| Bedrock | – | 71 |

## MISSISSIPPI RIVER ALLUVIUM

### ST. CHARLES COUNTY

**47 - 7 - 11ccb**
**Surface altitude: about 410 ft.**
**Depth to water, 7 ft., Oct. 28, 1969**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, fine, light tan | 2 | 2 |
| Clay, sandy, dark brown | 11 | 13 |
| Sand, medium, clayey, dark brown | 4 | 17 |
| Sand, medium to coarse, gray-brown | 15 | 32 |
| Sand, coarse to very coarse, gray-brown; contains some gravel | 90 | 122 |

**48 - 7 - 35abd**
**Surface altitude: about 416 ft.**
**Depth to water 9 ft., Jan. 23, 1969**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Clay, silty, brown | 17 | 17 |
| Clay, silty, sandy, gray, brown | 10 | 27 |
| Sand, very fine to fine, silty, gray-brown | 15 | 42 |
| Sand, very fine to very coarse, poorly sorted, gray-brown; contains some gravel | 5 | 47 |
| Sand, medium to coarse; contains gravel | 45 | 92 |
| Sand, coarse to very coarse, gray-brown; contains some gravel | 16 | 108 |
| Gravel and boulders | 1 | 109 |
| Bedrock | – | 109 |

**48 - 6 - 15ada**
**Surface altitude: about 423 ft.**
**Depth to water, 3 ft., Feb. 6, 1969**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Clay, dark gray | 15 | 15 |
| Silt, clayey, sandy, dark gray; contains gravel | 12 | 27 |
| Sand, fine to medium, dark gray | 10 | 37 |
| Sand, medium to coarse, gray; contains some gravel | 5 | 42 |
| Sand, very coarse, gray; contains much gravel | 5 | 47 |
| Sand, coarse, silty, gray; contains some gravel | 45 | 92 |
| Sand, coarse to very coarse, gray-brown; contains gravel | 10 | 102 |
| Sand and gravel | 8 | 110 |
| Bedrock | – | 110 |

**48 - 6 - 22ada**
**Surface altitude: about 440 ft.**
**Depth to water, 21 ft., Feb. 6, 1969**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Clay, silty, gray | 2 | 2 |
| Silt, sandy, clayey, brown | 10 | 12 |
| Sand, very fine to fine, silty, brown | 15 | 27 |
| Sand, fine to medium, brown | 5 | 32 |
| Sand, medium to coarse, brown | 5 | 37 |
| Sand, coarse to very coarse, brown; contains trace of gravel | 5 | 42 |
| Sand, medium to coarse, gray-brown | 10 | 52 |
| Sand, fine to medium, gray | 20 | 72 |
| Sand, medium to coarse, gray; contains trace of gravel | 5 | 77 |
| Sand, coarse to very coarse, gray-brown; contains gravel | 25 | 102 |
| Sand, medium to coarse; contains some gravel | 20 | 122 |

**47 - 5 - 14bca**
**Surface altitude: about 430 ft.**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, very fine to fine, brown | 7 | 7 |
| Clay, brown | 16 | 23 |
| Sand, very fine to fine, silty, gray-brown | 9 | 32 |
| Sand, fine to medium, gray-brown | 5 | 37 |
| Sand, medium to gray-brown | 5 | 42 |
| Sand, fine to very coarse, poorly sorted, gray-brown | 10 | 52 |
| Sand, coarse, gray-brown | 20 | 72 |
| Sand, coarse to very coarse; contains some gravel | 25 | 97 |
| Sand, very coarse, gray-brown; contains some gravel | 12 | 109 |
| Bedrock | – | 109 |

**44 - 1 - 14cab**
**Surface altitude: about 468 ft.**
**Depth to water, 14 ft., Feb. 10, 1967**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Silt, clayey, dark brown | 1 | 1 |
| Silt, light brown | 5 | 6 |
| Sand, very fine to fine, silty, clayey, brown | 10 | 16 |
| Sand, fine to medium, gray-brown | 15 | 31 |
| Sand, medium, gray-brown, some coarse, trace of very coarse sand | 10 | 41 |
| Sand, medium to coarse, gray-brown, some very coarse sand, some very fine gravel | 10 | 51 |
| Sand, medium, gray-brown, some coarse to very coarse sand, contains some gravel from 62-66 ft. | 29 | 80 |
| Bedrock | – | 80 |

**44 - 1 - 23cab**
**Surface altitude: about 471 ft.**
**Depth to water, 18 ft., Feb. 10, 1967**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Clay, silty, brown | 1 | 1 |
| Sand, fine, tan, some very fine | 8 | 9 |
| Clay, dark brown | 2 | 11 |
| Sand, fine to medium, light brown, trace of very coarse | 15 | 26 |
| Sand, medium, gray-brown, some coarse, some fine; gravel lens from 37 to 39 ft. | 15 | 41 |
| Sand, medium tó coarse, some very coarse sand, some very fine gravel | 15 | 56 |
| Sand, coarse to very coarse, some medium sand, some very fine to fine gravel | 5 | 61 |
| Sand, very coarse, and very fine gravel | 44 | 105 |
| Bedrock | – | 105 |

## ST. LOUIS COUNTY

| **47 - 5 - 28ddd**<br>**Surface altitude: about 437 ft.**<br>**Depth to water, 17 ft.,Feb. 10, 1967** | **Thickness (feet)** | **Depth (feet)** |
|---|---|---|
| Clay, silty, gray-brown | 4 | 4 |
| Silt, light gray-brown | 6 | 10 |
| Sand, medium, light brown | 16 | 26 |
| Sand, medium to coarse, gray-brown, some very coarse, trace of very fine gravel | 20 | 46 |
| Sand, medium to very coarse, gray-brown, trace of very fine to fine gravel | 15 | 61 |
| Sand, coarse to very coarse, gray-brown, some medium sand, some very fine to medium gravel | 10 | 71 |
| Sand, very coarse, gray-brown, some medium to coarse sand, much very fine gravel, some fine to medium gravel | 45 | 116 |
| Bedrock | — | 116 |

| **47 - 5 - 29 dbd**<br>**Surface altitude: about 440 ft.**<br>**Depth to water, 24 ft.,Feb. 10, 1967** | **Thickness (feet)** | **Depth (feet)** |
|---|---|---|
| Sand, very fine to fine, silty, brown | 11 | 11 |
| Sand, medium, light tan | 10 | 21 |
| Sand, medium to coarse, tan, some very coarse sand from 26 to 36 feet | 15 | 36 |
| Sand, coarse, some medium, some very coarse, trace of very fine gravel | 20 | 56 |
| Sand, very coarse, gray-brown, some medium to coarse sand, much very fine to fine gravel | 10 | 66 |
| Sand, very coarse, much very fine gravel, some medium to coarse sand, some gravel 1 inch long | 30 | 96 |
| Bedrock | — | 96 |

# APPENDIX 2

Table 1

Selected analyses of water from bedrock wells in St. Louis area by aquifer group

| | | | | Milligrams per liter | | | | | | | | | | | | | | Hardness as $CaCO_3$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well number | Depth (feet) | Date of collection | Temperature (°C) | Silica ($SiO_2$) | Iron (Fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Carbonate ($CO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Dissolved solids (residue at 180°C) | Calcium Magnesium | Noncarbonate | Specific conductance (Micromhos at 25°C) | pH | Color |
| Group 1 (post-Maquoketa) Aquifers | | | | | | | | | | | | | | | | | | | | | | |
| 43-6-31 dab | 301 | 12-19-60 | -- | 4.8 | 0.23 | ---- | 81 | 45 | 11 | --- | 466 | 0 | 11 | 4.0 | 0.3 | 0.0 | 404 | 387 | 4 | -- | -- | -- |
| 44-6-31 ccb | 409 | 6-11-41 | -- | 12 | ---- | ---- | 262 | 131 | 1310 | --- | 339 | 0 | 262 | 2,360 | --- | --- | 5,050 | 1190 | 913 | -- | -- | -- |
| 45-4-12 cdd | 383 | 5-17-35 | -- | 10 | .05 | ---- | 40 | 27 | 48 | 0.0 | 316 | 0 | 26 | 22 | 3.2 | 2.0 | 372 | 211 | --- | -- | -- | -- |
| 46-2-1 bcb | 220 | 3-7-61 | -- | 4.2 | .13 | ---- | 65 | 28 | 14 | --- | 331 | 4 | 11 | 1.5 | .1 | --- | 311 | 275 | 0 | -- | -- | -- |
| 46-6-35 ddc | 790 | 9-20-38 | -- | 6.8 | .14 | ---- | 211 | 120 | 1560 | --- | 305 | 0 | 267 | 2,670 | --- | --- | 5,400 | 1020 | 770 | -- | -- | -- |
| 46-7-20 dbc | 655 | 2-27-36 | -- | 6.0 | .12 | ---- | 45 | 25 | 124 | --- | 416 | 3 | 84 | 36 | 3.0 | .0 | 558 | 214 | --- | -- | -- | -- |
| 47-6-34 bac | 513 | 1-27-38 | -- | 8.4 | .12 | ---- | 30 | 16 | 246 | --- | 396 | 1 | 296 | 34 | 3.8 | 3.5 | 916 | 139 | --- | -- | -- | -- |
| Group 2 (Kimmswick-Joachim) Aquifers | | | | | | | | | | | | | | | | | | | | | | |
| 44-5-20 adb | 365 | 4-26-41 | -- | 5.6 | ---- | ---- | 74 | 26 | 28 | --- | 339 | 0 | 49 | 14 | --- | --- | 424 | 290 | 12 | -- | -- | -- |
| 46-1-15 cdb | 370 | 3-3-61 | -- | 4.2 | .16 | ---- | 62 | 39 | 27 | --- | 354 | 14 | 15 | 5.0 | .7 | 1.2 | 355 | 313 | --- | -- | -- | -- |
| 46-4-17 bcb | 810 | 3-28-61 | -- | 16 | 1.0 | ---- | 124 | 74 | 1120 | --- | 340 | 0 | 357 | 1,740 | 2.5 | .1 | 4,070 | 616 | 337 | -- | -- | -- |
| 46-5-2 cb | 915 | 6-1-34 | -- | 19 | .20 | ---- | 94 | 41 | 12 | --- | 454 | 13 | 6.4 | 6.2 | --- | 7.4 | 459 | 403 | --- | -- | -- | -- |
| 47-7-35 dca | 1300 | ------ | -- | 4.0 | 4.5 | ---- | 252 | 188 | 5960 | --- | 247 | 0 | 23 | 10,000 | --- | .4 | 17,500 | --- | --- | -- | -- | -- |
| 48-6-22 aca | 619 | 2-16-34 | -- | 1.2 | .10 | ---- | 125 | 82 | 1220 | --- | 131 | 5 | 376 | 1,900 | --- | .5 | 4,710 | 649 | 542 | -- | -- | -- |
| Group 3 (St. Peter-Everton) Aquifers | | | | | | | | | | | | | | | | | | | | | | |
| 39-7-6 dba | 181 | 11-27-60 | -- | 7.7 | .11 | ---- | 106 | 56 | 25 | --- | 476 | 0 | 124 | 8.3 | .3 | 4.6 | 604 | 497 | 106 | -- | -- | -- |
| 42-4-5 bab | 185 | 1-6-61 | -- | 5.6 | .14 | ---- | 83 | 31 | 3.5 | --- | 379 | 6 | 11 | 2.8 | --- | --- | 335 | 335 | 14 | -- | -- | -- |
| 42-5-23 dd | 150 | 2-3-61 | -- | 3.3 | .15 | ---- | 78 | 28 | 2.6 | --- | 359 | 0 | 7.8 | 2.0 | .3 | 0 | 311 | 309 | 14 | -- | -- | -- |
| 43-5-4 bdb | 800 | 5-9-62 | -- | 8.0 | .04 | ---- | 46 | 25 | 9.8 | --- | 252 | 0 | 19 | 12 | .7 | .1 | 270 | 216 | 12 | -- | -- | -- |
| 45-3-7 dbb | 535 | 3-7-61 | -- | 6.8 | .09 | ---- | 85 | 35 | 17 | --- | 366 | 14 | 17 | 13 | .3 | 16 | 420 | 358 | 34 | -- | -- | -- |
| 44-4-1 add | 798 | 2-25-37 | -- | 8.8 | .15 | ---- | 325 | 149 | 1810 | --- | 267 | -- | 442 | 3,320 | --- | 0 | 7,270 | 1,420 | --- | -- | -- | -- |
| 47-1-19 abc | 770 | 7-30-68 | -- | 8.0 | .04 | ---- | 68 | 35 | 40 | 9.6 | 420 | 0 | 70 | 7.9 | .7 | --- | 478 | 313 | 0 | -- | -- | -- |
| 47-3-25 dcd | 820 | 12-7-67 | -- | 7.0 | .85 | ---- | 66 | 35 | 200 | 11 | 349 | 0 | 56 | 291 | 1.5 | 0 | 915 | 307 | 21 | -- | -- | -- |
| 48-2-35 add | 810 | 5-18-34 | -- | 8.0 | .60 | ---- | 6.5 | 3.4 | 290 | --- | 456 | 40 | 150 | 28 | --- | 16 | 777 | 30 | --- | -- | -- | -- |
| Group 4 (Powell-Gasconade) Aquifers | | | | | | | | | | | | | | | | | | | | | | |
| 39-4-1 bcb | 185 | 11-16-60 | -- | 9.7 | .08 | ---- | 161 | 116 | 22 | --- | 597 | 0 | 386 | 12 | 0 | 11 | 1,110 | 881 | 391 | -- | -- | -- |
| 41-2-13 cdb | 305 | 12-10-60 | -- | 7.5 | .07 | ---- | 70 | 43 | 6 | --- | 389 | 7 | 12 | 3.5 | --- | .1 | 352 | 350 | 19 | -- | -- | -- |
| 42-6-30 adc | 562 | 12-7-36 | -- | 12 | .12 | ---- | 141 | 92 | 793 | --- | 134 | 0 | 128 | 1,580 | .1 | --- | 3,100 | 730 | 620 | -- | -- | -- |
| 43-3-18 ccd | 585 | 9-5-61 | -- | 5.0 | .08 | ---- | 68 | 36- | 13 | --- | 348 | 0 | 16 | 2.5 | .1 | 0 | 314 | 316 | 30 | -- | -- | -- |
| 44-1-11 dcd | 352 | 3-3-61 | -- | 18 | .20 | ---- | 104 | 54 | 37 | --- | 516 | 0 | 48 | 25 | .1 | 9.7 | 600 | 484 | 61 | -- | -- | -- |
| 44-3-35 daa | 820 | 1-18-63 | -- | 6.3 | 1.6 | ---- | 80 | 36 | 27 | --- | 309 | 24 | 23 | 44 | .2 | 0 | 422 | 350 | 56 | -- | -- | -- |
| 44-5-16 abd | 1345 | 6-1-34 | -- | 8.0 | .20 | ---- | 464 | 187 | 2570 | --- | 250 | 8 | 563 | 4,370 | 2.8 | .1 | 4,650 | 1,930 | --- | -- | -- | -- |
| 45-3-29 acc | 1072 | 6-12-40 | -- | 4.0 | ---- | ---- | 52 | 27 | 14 | --- | 295 | 4 | 22 | 6.5 | --- | --- | 324 | 238 | --- | -- | -- | -- |
| 47-2-19 cca | 1337 | 1-7-63 | -- | 6.0 | 4.0 | ---- | 63 | 28 | 37 | 4.0 | 341 | -- | 45 | 24 | .8 | .1 | 406 | 274 | --- | -- | -- | -- |
| 47-3-20 ada | 1500 | 8-18-66 | -- | 8.0 | .01 | ---- | 47 | 25 | 100 | 8.8 | 364 | 0 | 68 | 43 | 1.1 | 1.2 | 561 | 220 | --- | -- | -- | -- |
| Group 5 (Eminence-Lamotte) Aquifers | | | | | | | | | | | | | | | | | | | | | | |
| 39-3-14 baa | 350 | 11-28-60 | -- | 5.5 | 0.06 | ---- | 68 | 38 | 26 | --- | 336 | 12 | 51 | 11 | 0.5 | 0.2 | 387 | 327 | 31 | -- | -- | -- |
| 39-5-31 caa | 800 | 6-12-63 | -- | 6.0 | .20 | ---- | 70 | 41 | 2.3 | 1.2 | 403 | 0 | 18 | 4.8 | .1 | --- | 406 | 344 | 13 | -- | -- | -- |
| 40-6-6 cdb | 865 | ------- | -- | 8.0 | .04 | ---- | 61 | 32 | 2.9 | 2.0 | 310 | -- | 18 | 3.7 | --- | .4 | 337 | 284 | 30 | -- | -- | -- |
| 41-4-27 ddb | 1100 | 8-10-65 | -- | --- | .30 | ---- | 68 | 44 | 7.4 | 1.5 | 403 | 0 | -- | 8.1 | .1 | .3 | --- | 350 | 20 | -- | -- | -- |
| 47-6-18 add | 2755 | 9-23-40 | -- | 8.4 | ---- | ---- | 283 | 112 | 1620 | --- | 302 | 0 | 478 | 2,690 | 2.1 | --- | 6,060 | 1170 | 921 | -- | -- | -- |

Table 2

Selected analyses of water from wells in alluvial deposits in St. Charles, St. Louis, and Jefferson Counties, Missouri

| Well number | Depth | Date of collection | Temperature (°C) | milligrams per liter: Silica ($SiO_2$) | Iron (Fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Carbonate ($CO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Dissolved solids (residue at 180°C) | Hardness as $CaCO_3$: Calcium Magnesium | Noncarbonate | Specific conductance (Micromhos at 25°C) | pH | Color |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Meramec River Alluvium | | | | | | | | | | | | | | | | | | | | | | |
| 43-3-10 bdc | 37 | 6-6-68 | 14 | 11 | 2.2 | 0.50 | 86 | 16 | 6.5 | 0.8 | 342 | 0 | 10 | 6.2 | 0.2 | 0.0 | 321 | 281 | 0 | 559 | 7.7 | 7 |
| 43-3-11 cdd | 24 | 6-6-68 | 13 | 9.1 | 1.9 | .32 | 150 | 20 | 4.0 | 1.4 | 478 | 0 | 58 | 5.8 | .0 | .4 | 486 | 456 | 64 | 765 | 7.8 | 3 |
| 43-3-22 daa | 42 | 6-5-68 | 16 | 11 | 7.5 | 1.6 | 20 | 9.3 | 5.0 | 1.2 | 100 | 0 | 13 | 2.7 | .2 | .0 | 122 | 88 | 6 | 210 | 7.1 | 7 |
| 44-4-31 dca | 40 | 6-6-68 | 14 | 12 | 1.9 | 1.4 | 77 | 32 | 50 | 2.5 | 376 | 0 | 33 | 72 | .2 | .0 | 476 | 324 | 16 | 837 | 7.7 | 3 |
| 44-4-14 ccc | 42 | 6-7-68 | 13 | 11 | .11 | .00 | 60 | 18 | 28 | 1.8 | 212 | 0 | 39 | 47 | .1 | 9.3 | 337 | 224 | 50 | 569 | 7.4 | 5 |
| 44-5-10 ccc | 53 | 6-4-68 | 14 | 8.9 | .70 | 1.3 | 56 | 15 | 42 | 3.4 | 185 | 0 | 72 | 54 | .1 | .0 | 351 | 201 | 50 | 593 | 7.4 | 5 |
| 44-5-17 cdb | 63 | 8-27-69 | 14 | 12 | .34 | .61 | 87 | 26 | 140 | 4.6 | 158 | 0 | 108 | 277 | .1 | .0 | 742 | 324 | 195 | 1290 | 7.6 | 2 |
| 44-5-18 dda | 62 | 8-27-69 | 13.5 | 13 | .00 | .33 | 57 | 16 | 26 | 2.2 | 158 | 0 | 88 | 32 | .0 | 4.2 | 331 | 208 | 78 | 536 | 7.5 | 2 |
| 44-5-27 bad | 58 | 6-4-68 | 15 | 10 | 3.6 | 1.2 | 98 | 33 | 9.4 | 1.4 | 403 | 0 | 62 | 8.4 | .3 | .5 | 438 | 380 | 50 | 747 | 7.7 | 3 |
| 43-5-13 cab | 48 | 6-11-68 | ---- | 9.2 | 3.4 | .80 | 51 | 14 | 25 | 1.8 | 212 | 0 | 32 | 24 | .0 | .3 | 283 | 185 | 11 | 467 | 7.4 | 2 |
| 43-5-1 ccd | 43 | 6-7-68 | 12 | 9.1 | .10 | .00 | 36 | 15 | 7.7 | .9 | 132 | 0 | 34 | 18 | .1 | 4.8 | 201 | 152 | 44 | 391 | 7.3 | 5 |
| Mississippi and Missouri Rivers Alluvium | | | | | | | | | | | | | | | | | | | | | | |
| 44-1-23 cab | 46 | 2-3-67 | 15 | 26 | 2.8 | 2.7 | 172 | 38 | 11 | 5.3 | 662 | 0 | 55 | 2.4 | .2 | .0 | 641 | 586 | 42 | 1020 | 7.1 | 0 |
| 44-3-15 bbd | 47 | 10-30-69 | 13 | 17 | 5.7 | .82 | 107 | 20 | 16 | 1.0 | 386 | 0 | 46 | 15 | .2 | .0 | 419 | 349 | 32 | 689 | 7.6 | 1 |
| 47-4-23 bdd | 100 | 10-30-69 | 13 | 37 | 8.7 | .39 | 95 | 37 | 16 | 2.0 | 508 | 0 | .4 | 1.7 | .3 | 4.1 | 452 | 389 | 0 | 734 | 7.6 | 5 |
| 47-5-2 bdd | 46 | 10-29-69 | 14 | 24 | 1.0 | .15 | 46 | 10 | 4.0 | 2.6 | 184 | 0 | 17 | .5 | .5 | 2.8 | 205 | 156 | 5 | 316 | 7.8 | 0 |
| 47-7-13 dcc | 46 | 10-27-69 | 14 | 24 | 10 | .80 | 133 | 31 | 7.0 | 3.9 | 512 | 0 | 70 | 2.0 | .3 | .1 | 552 | 460 | 40 | 872 | 8.0 | 5 |
| 47-8-20 aad | 50 | 10-27-69 | 14 | 30 | 29 | 2.1 | 169 | 47 | 16 | 5.4 | 784 | 0 | 1.6 | 3.8 | .2 | .3 | 690 | 616 | 0 | 1070 | 8.1 | 10 |
| 48-2-12 bbd | 39 | 10-30-69 | 13.5 | 24 | 8.0 | .97 | 90 | 20 | 11 | 1.0 | 312 | 0 | 72 | 7.0 | .2 | .0 | 388 | 307 | 51 | 618 | 7.3 | 2 |
| 48-3-16 bd | 89 | 10-30-69 | 13.5 | 29 | 14 | 1.1 | 76 | 17 | 9.2 | 1.3 | 316 | 0 | 7.2 | 5.9 | .2 | 1.0 | 304 | 260 | 0 | 504 | 7.5 | 2 |
| 48-5-23 bad | 56 | 10-28-69 | 12 | 27 | 9.3 | 1.2 | 93 | 23 | 8.2 | 4.6 | 340 | 0 | 53 | 4.6 | .4 | .2 | 392 | 327 | 48 | 884 | 8.1 | 15 |
| 48-6-15 bcb | 116 | 10-28-69 | 14 | 27 | 7.6 | .18 | 120 | 32 | 11 | 4.6 | 544 | 0 | 13 | 3.2 | .3 | 2.8 | 489 | 431 | 0 | 808 | 8.1 | 5 |
| 48-7-20 cac | 47 | 10-28-69 | 13 | 27 | 4.8 | .53 | 118 | 26 | 4.3 | 4.6 | 460 | 0 | 25 | 3.2 | .2 | 1.1 | 441 | 402 | 24 | 716 | 8.2 | 5 |
| 49-5-34 ddd | 52 | 10-30-69 | 12 | 30 | 9.7 | .62 | 82 | 17 | 8.8 | 1.9 | 325 | 0 | 28 | .9 | .2 | .5 | 339 | 275 | 8 | 526 | 8.0 | 35 |

# APPENDIX 3

## STREAMFLOW STATISTICS AND FLOW-VARIABILITY DATA FOR MISSISSIPPI AND MISSOURI RIVER STATIONS

Statistical and flow-variability data are presented so that water managers and planners will have values of daily streamflow in a form which is readily adaptable to their needs.

Further analysis of these data was not justified at this time. However, future research plans of the Water Resources Division include systems analyses of the Mississippi and Missouri basins.

Scientific notation (for example, $0.036=0.36 \times 10^{-1}$) is used in the statistics of monthly and annual means. In this format a decimal is always placed immediately to the left of the first digit in the mantissa, with the two digits immediately after the "E" indicating the exponent of 10 needed to compute the correct data value. The following examples illustrate the use of the "E" format:

$$-0.424 \text{ E } -01 = -0.424 \times 10^{-1} = -0.0424$$
$$0.424 \text{ E } -01 = 0.424 \times 10^{-1} = 0.0424$$
$$0.424 \text{ E } 00 = 0.424 \times 10^{0} = 0.424$$
$$0.424 \text{ E } 01 = 0.424 \times 10^{1} = 4.24$$

The lowest and highest mean discharges for each year and their ranking are shown for each of the three stations in this appendix. The order numbers are included for the convenience of the user who may want to construct frequency curves for these stations. Note that climatic year data (April 1 - March 31) used in computation of lowest mean discharges and water year data (October 1 - September 30) are used in computation of highest-mean-discharge data.

Tables of duration of daily discharges are shown for each station. A cumulative frequency curve (flow-duration curve) showing the percent of time during which specified discharges were exceeded in a given period may be plotted from these data. Logarithmic probability paper is recommended for these plots because it tends to straighten the flow-duration curve.

## MISSISSIPPI RIVER AT ALTON, ILL. 05587500

STATISTICS ON NORMAL MONTHLY MEANS(ALL DAYS)

BY ROWS (MEAN, VARIANCE, STANDARD DEVIATION, SKEWNESS, COEFF. OF VARIATION, PERCENTAGE OF AVERAGE FLOW, FIRST ORDER SERIAL CORRELATION COEFF.)

| OCT | NOV | DEC | JAN | FEB | MARCH | APRIL | MAY | JUNE | JULY | AUG | SEPT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5724E 05 | 0.6108E 05 | 0.5332E 05 | 0.6088E 05 | 0.7309E 05 | 0.1227E 06 | 0.1726E 06 | 0.1538E 06 | 0.1337E 06 | 0.1039E 06 | 0.6108E 05 | 0.5700E 05 |
| 0.1402E 10 | 0.1375E 10 | 0.4394E 09 | 0.1063E 10 | 0.9580E 09 | 0.2532E 10 | 0.4330E 10 | 0.4365E 10 | 0.4161E 10 | 0.2414E 10 | 0.5500E 09 | 0.7003E 09 |
| 0.3744E 05 | 0.3708E 05 | 0.2096E 05 | 0.3260E 05 | 0.3095E 05 | 0.5032E 05 | 0.6581E 05 | 0.6607E 05 | 0.6450E 05 | 0.4913E 05 | 0.2345E 05 | 0.2646E 05 |
| 0.1859E 01 | 0.1872E 01 | 0.8341E 00 | 0.1539E 01 | 0.2897E 00 | -0.6154E-01 | 0.4287E 00 | 0.5181E 00 | 0.9636E 00 | 0.8350E 00 | 0.6390E 00 | 0.1782E 01 |
| 0.6540E 00 | 0.6070E 00 | 0.3931E 00 | 0.5354E 00 | 0.4235E 00 | 0.4100E 00 | 0.3812E 00 | 0.4297E 00 | 0.4826E 00 | 0.4730E 00 | 0.3840E 00 | 0.4642E 00 |
| 0.5155E 01 | 0.5501E 01 | 0.4802E 01 | 0.5483E 01 | 0.6583E 01 | 0.1105E 02 | 0.1555E 02 | 0.1385E 02 | 0.1204E 02 | 0.9353E 01 | 0.5501E 01 | 0.5134E 01 |

STATISTICS ON NORMAL ANNUAL MEANS(ALL DAYS)

| MEAN | VARIANCE | STANDARD DEVIATION | SKEWNESS | COEFF. OF VARIATION | SERIAL CORR |
|---|---|---|---|---|---|
| 0.9252E 05 | 0.7858E 09 | 0.2803E 05 | 0.1993E-01 | 0.3030E 00 | 0.2388E 00 |

## MISSOURI RIVER AT HERMANN, MO. 06934500

STATISTICS ON NORMAL MONTHLY MEANS(ALL DAYS)

BY ROWS (MEAN, VARIANCE, STANDARD DEVIATION, SKEWNESS, COEFF. OF VARIATION, PERCENTAGE OF AVERAGE FLOW, FIRST ORDER SERIAL CORRELATION COEFF.)

| OCT | NOV | DEC | JAN | FEB | MARCH | APRIL | MAY | JUNE | JULY | AUG | SEPT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5122E 05 | 0.5095E 05 | 0.3367E 05 | 0.3492E 05 | 0.4754E 05 | 0.7767E 05 | 0.1057E 06 | 0.9970E 05 | 0.1228E 06 | 0.9624E 05 | 0.5586E 05 | 0.5631E 05 |
| 0.8594E 09 | 0.1028E 10 | 0.2456E 09 | 0.3191E 09 | 0.6272E 09 | 0.1538E 10 | 0.4076E 10 | 0.2716E 10 | 0.5363E 10 | 0.4885E 10 | 0.6737E 09 | 0.1334E 10 |
| 0.2932E 05 | 0.3206E 05 | 0.1567E 05 | 0.1786E 05 | 0.2504E 05 | 0.3921E 05 | 0.6384E 05 | 0.5212E 05 | 0.7323E 05 | 0.6989E 05 | 0.2596E 05 | 0.3653E 05 |
| 0.2256E 01 | 0.1687E 01 | 0.9223E 00 | 0.8141E 00 | 0.1337E 01 | 0.8428E 00 | 0.1222E 01 | 0.1017E 01 | 0.1281E 01 | 0.3376E 01 | 0.1512E 01 | 0.2774E 01 |
| 0.5724E 00 | 0.6293E 00 | 0.4654E 00 | 0.5115E 00 | 0.5267E 00 | 0.5049E 00 | 0.6039E 00 | 0.5227E 00 | 0.5964E 00 | 0.7262E 00 | 0.4646E 00 | 0.6488E 00 |
| 0.6151E 01 | 0.6119E 01 | 0.4044E 01 | 0.4194E 01 | 0.5710E 01 | 0.9328E 01 | 0.1270E 02 | 0.1197E 02 | 0.1475E 02 | 0.1156E 02 | 0.6710E 01 | 0.6763E 01 |

STATISTICS ON NORMAL ANNUAL MEANS(ALL DAYS)

| MEAN | VARIANCE | STANDARD DEVIATION | SKEWNESS | COEFF. OF VARIATION | SERIAL CORR |
|---|---|---|---|---|---|
| 0.6939E 05 | 0.6849E 09 | 0.2617E 05 | 0.5932E 00 | 0.3772E 00 | 0.4023E 00 |

## MISSISSIPPI RIVER AT ST. LOUIS, MO. 07010000

STATISTICS ON NORMAL MONTHLY MEANS(ALL DAYS)

BY ROWS (MEAN, VARIANCE, STANDARD DEVIATION, SKEWNESS, COEFF. OF VARIATION, PERCENTAGE OF AVERAGE FLOW, FIRST ORDER SERIAL CORRELATION COEFF.)

| OCT | NOV | DEC | JAN | FEB | MARCH | APRIL | MAY | JUNE | JULY | AUG | SEPT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1131E 06 | 0.1121E 06 | 0.8669E 05 | 0.9620E 05 | 0.1229E 06 | 0.2006E 06 | 0.2808E 06 | 0.2521E 06 | 0.2558E 06 | 0.2065E 06 | 0.1218E 06 | 0.1182E 06 |
| 0.3908E 10 | 0.4180E 10 | 0.1096E 10 | 0.2406E 10 | 0.2908E 10 | 0.6577E 10 | 0.1366E 11 | 0.1081E 11 | 0.1488E 11 | 0.1185E 11 | 0.1737E 10 | 0.3573E 10 |
| 0.6251E 05 | 0.6465E 05 | 0.3311E 05 | 0.4905E 05 | 0.5392E 05 | 0.8110E 05 | 0.1169E 06 | 0.1040E 06 | 0.1220E 06 | 0.1089E 06 | 0.4163E 05 | 0.5977E 05 |
| 0.1907E 01 | 0.2019E 01 | 0.8313E 00 | 0.1260E 01 | 0.4990E 00 | 0.8266E-01 | 0.6386E 00 | 0.6612E 00 | 0.1131E 01 | 0.2148E 01 | 0.7594E 00 | 0.2046E 01 |
| 0.5526E 00 | 0.5767E 00 | 0.3820E 00 | 0.5098E 00 | 0.4388E 00 | 0.4043E 00 | 0.4162E 00 | 0.4124E 00 | 0.4767E 00 | 0.5272E 00 | 0.3423E 00 | 0.5056E 00 |
| 0.5751E 01 | 0.5700E 01 | 0.4407E 01 | 0.4891E 01 | 0.6248E 01 | 0.1020E 02 | 0.1428E 02 | 0.1282E 02 | 0.1301E 02 | 0.1050E 02 | 0.6192E 01 | 0.6011E 01 |

STATISTICS ON NORMAL ANNUAL MEANS(ALL DAYS)

| MEAN | VARIANCE | STANDARD DEVIATION | SKEWNESS | COEFF. OF VARIATION | SERIAL CORR |
|---|---|---|---|---|---|
| 0.1639E 06 | 0.2487E 10 | 0.4987E 05 | 0.1023E 00 | 0.3043E 00 | 0.3487E 00 |

## MISSISSIPPI RIVER AT ALTON, ILL. 05587500

LOWEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

| YEAR | 1 | 3 | 7 | 14 | 30 | 60 | 90 | 120 | 183 | ANNUAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1934 | 15000.0 1 | 15800.0 1 | 19600.0 1 | 22600.0 4 | 25100.0 4 | 27700.0 5 | 29100.0 3 | 30000.0 2 | 30800.0 2 | 70500.0 7 |
| 1935 | 23900.0 14 | 24100.0 13 | 25700.0 11 | 27700.0 13 | 29600.0 11 | 32500.0 11 | 33000.0 6 | 33600.0 6 | 37700.0 8 | 61900.0 5 |
| 1936 | 27200.0 19 | 28500.0 18 | 31000.0 21 | 32900.0 21 | 34800.0 19 | 36800.0 18 | 41000.0 19 | 46600.0 21 | 46100.0 16 | 100000.0 19 |
| 1937 | 21600.0 10 | 21600.0 9 | 21700.0 7 | 21900.0 2 | 22300.0 2 | 25300.0 1 | 30400.0 5 | 41100.0 17 | 42200.0 11 | 79000.0 11 |
| 1941 | 25300.0 15 | 25800.0 15 | 27200.0 15 | 28300.0 15 | 30400.0 14 | 30900.0 8 | 35900.0 14 | 40800.0 16 | 44300.0 13 | 56900.0 3 |
| 1942 | 21000.0 9 | 21900.0 10 | 26200.0 12 | 26600.0 11 | 28600.0 9 | 38300.0 20 | 58700.0 25 | 68300.0 27 | 93900.0 28 | 113000.0 23 |
| 1943 | 48100.0 31 | 49000.0 31 | 50100.0 31 | 54900.0 31 | 71500.0 31 | 83100.0 30 | 86200.0 30 | 89200.0 29 | 95000.0 29 | 121000.0 27 |
| 1944 | 30600.0 25 | 31100.0 24 | 35100.0 25 | 37400.0 24 | 40300.0 24 | 43600.0 23 | 44200.0 21 | 46400.0 20 | 49600.0 21 | 120000.0 26 |
| 1945 | 30200.0 23 | 30600.0 23 | 31700.0 23 | 33300.0 22 | 34900.0 21 | 37200.0 19 | 38800.0 17 | 39400.0 14 | 44700.0 15 | 114000.0 24 |
| 1946 | 41100.0 30 | 43100.0 30 | 45900.0 30 | 47300.0 29 | 52800.0 29 | 58700.0 27 | 59900.0 26 | 66600.0 25 | 71300.0 25 | 135000.0 29 |
| 1947 | 34400.0 26 | 36300.0 27 | 37100.0 26 | 42200.0 26 | 51900.0 28 | 55300.0 25 | 58200.0 23 | 65600.0 24 | 70100.0 23 | 92000.0 16 |
| 1948 | 28000.0 20 | 28300.0 17 | 28700.0 16 | 29900.0 17 | 34800.0 20 | 39500.0 21 | 41000.0 20 | 42200.0 18 | 44600.0 14 | 128000.0 28 |
| 1949 | 15800.0 2 | 17600.0 2 | 22500.0 9 | 23500.0 6 | 25200.0 5 | 26500.0 3 | 28500.0 2 | 30000.0 3 | 38200.0 10 | 80200.0 13 |
| 1950 | 19000.0 6 | 20400.0 7 | 21600.0 6 | 23500.0 7 | 30800.0 15 | 33100.0 12 | 35100.0 12 | 35100.0 8 | 47400.0 18 | 79200.0 12 |
| 1951 | 22500.0 11 | 22900.0 11 | 24100.0 10 | 26400.0 10 | 28500.0 8 | 30400.0 7 | 33600.0 8 | 35400.0 9 | 37800.0 9 | 97900.0 18 |
| 1952 | 35400.0 28 | 39300.0 29 | 45100.0 29 | 52400.0 30 | 70200.0 30 | 89000.0 31 | 93000.0 31 | 95800.0 31 | 98200.0 30 | 153000.0 31 |
| 1953 | 25700.0 16 | 29000.0 20 | 29300.0 18 | 31000.0 18 | 32900.0 17 | 34800.0 15 | 38300.0 16 | 40000.0 15 | 47300.0 17 | 103000.0 21 |
| 1954 | 27100.0 18 | 27200.0 16 | 28900.0 17 | 29300.0 16 | 30100.0 12 | 32300.0 9 | 34800.0 11 | 36200.0 10 | 36800.0 5 | 75300.0 9 |
| 1955 | 36700.0 29 | 38800.0 28 | 43100.0 28 | 46600.0 28 | 50100.0 26 | 57900.0 26 | 61400.0 28 | 66800.0 26 | 71800.0 26 | 95500.0 17 |
| 1956 | 23800.0 13 | 25200.0 14 | 26300.0 14 | 27800.0 14 | 31200.0 16 | 33700.0 14 | 34300.0 9 | 34600.0 7 | 36400.0 4 | 61200.0 4 |
| 1957 | 17400.0 3 | 18800.0 3 | 19600.0 2 | 20500.0 1 | 21800.0 1 | 26400.0 2 | 29400.0 4 | 31300.0 4 | 35000.0 3 | 56600.0 2 |
| 1958 | 30200.0 24 | 31300.0 25 | 32900.0 24 | 33500.0 23 | 37200.0 22 | 42500.0 22 | 45400.0 22 | 46800.0 22 | 48400.0 20 | 79000.0 10 |
| 1959 | 18500.0 5 | 19600.0 4 | 22100.0 8 | 25400.0 9 | 28300.0 7 | 29200.0 6 | 33500.0 7 | 32500.0 5 | 37500.0 6 | 71600.0 8 |
| 1960 | 28400.0 22 | 29900.0 21 | 31200.0 22 | 38500.0 25 | 51100.0 27 | 51200.0 24 | 58600.0 24 | 64500.0 23 | 70900.0 24 | 90100.0 15 |
| 1961 | 26800.0 17 | 28600.0 19 | 30800.0 19 | 31800.0 19 | 33100.0 18 | 35700.0 17 | 39800.0 18 | 43900.0 19 | 47900.0 19 | 114000.0 25 |
| 1962 | 28200.0 21 | 30400.0 22 | 30800.0 20 | 32700.0 20 | 40200.0 23 | 60800.0 28 | 60500.0 27 | 72800.0 28 | 89400.0 27 | 110000.0 22 |
| 1963 | 23400.0 12 | 24100.0 12 | 26200.0 13 | 26700.0 12 | 29200.0 10 | 33500.0 13 | 35600.0 13 | 38500.0 12 | 49900.0 22 | 101000.0 20 |
| 1964 | 19200.0 7 | 19900.0 5 | 21500.0 5 | 22600.0 5 | 23200.0 3 | 26800.0 4 | 27300.0 1 | 27200.0 1 | 29000.0 1 | 51200.0 1 |
| 1965 | 17800.0 4 | 19900.0 6 | 20700.0 3 | 22200.0 3 | 27000.0 6 | 32300.0 10 | 34500.0 10 | 36300.0 11 | 37700.0 7 | 68100.0 6 |
| 1966 | 35100.0 27 | 36100.0 26 | 41300.0 27 | 43000.0 27 | 45400.0 25 | 63000.0 29 | 79000.0 29 | 90000.0 30 | 98500.0 31 | 141000.0 30 |
| 1967 | 19200.0 8 | 20900.0 8 | 21500.0 4 | 23600.0 8 | 30300.0 13 | 35300.0 16 | 36000.0 15 | 38900.0 13 | 42300.0 12 | 82400.0 14 |

MISSISSIPPI RIVER AT ALTON, ILL. 05587500

HIGHEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

| YEAR | 1 | | 3 | | 7 | | 15 | | 30 | | 60 | | 90 | | 120 | | 183 | | ANNUAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1934 | 97200.0 | 32 | 96800.0 | 32 | 94700.0 | 32 | 88800.0 | 32 | 75800.0 | 32 | 58900.0 | 32 | 52100.0 | 32 | 47100.0 | 32 | 42900.0 | 32 | 37200.0 | 32 |
| 1935 | 231000.0 | 19 | 228000.0 | 19 | 216000.0 | 19 | 203000.0 | 19 | 199000.0 | 15 | 180000.0 | 16 | 172000.0 | 13 | 170000.0 | 11 | 150000.0 | 11 | 107000.0 | 13 |
| 1936 | 218000.0 | 22 | 209000.0 | 23 | 189000.0 | 25 | 181000.0 | 24 | 176000.0 | 20 | 168000.0 | 18 | 156000.0 | 18 | 137000.0 | 19 | 103000.0 | 24 | 72700.0 | 25 |
| 1937 | 253000.0 | 15 | 251000.0 | 14 | 240000.0 | 15 | 208000.0 | 17 | 176000.0 | 21 | 153000.0 | 22 | 155000.0 | 19 | 145000.0 | 17 | 125000.0 | 16 | 86500.0 | 15 |
| 1940 | 128000.0 | 31 | 114000.0 | 31 | 102000.0 | 31 | 96700.0 | 31 | 87600.0 | 31 | 77300.0 | 31 | 77000.0 | 31 | 71100.0 | 31 | 64600.0 | 31 | 47200.0 | 31 |
| 1941 | 219000.0 | 20 | 214000.0 | 22 | 207000.0 | 22 | 194000.0 | 20 | 170000.0 | 23 | 140000.0 | 24 | 129000.0 | 25 | 117000.0 | 26 | 95600.0 | 26 | 72800.0 | 24 |
| 1942 | 253000.0 | 16 | 248000.0 | 15 | 241000.0 | 14 | 230000.0 | 14 | 202000.0 | 14 | 183000.0 | 14 | 160000.0 | 16 | 161000.0 | 13 | 150000.0 | 12 | 133000.0 | 2 |
| 1943 | 434000.0 | 1 | 416000.0 | 1 | 387000.0 | 1 | 336000.0 | 5 | 296000.0 | 6 | 268000.0 | 6 | 244000.0 | 5 | 227000.0 | 4 | 191000.0 | 2 | 142000.0 | 1 |
| 1944 | 392000.0 | 2 | 386000.0 | 2 | 371000.0 | 3 | 343000.0 | 3 | 295000.0 | 7 | 274000.0 | 5 | 256000.0 | 2 | 233000.0 | 3 | 182000.0 | 4 | 115000.0 | 9 |
| 1945 | 307000.0 | 11 | 303000.0 | 11 | 296000.0 | 11 | 284000.0 | 10 | 265000.0 | 9 | 238000.0 | 9 | 239000.0 | 6 | 223000.0 | 7 | 175000.0 | 7 | 112000.0 | 10 |
| 1946 | 313000.0 | 10 | 311000.0 | 10 | 299000.0 | 10 | 266000.0 | 11 | 241000.0 | 11 | 185000.0 | 13 | 167000.0 | 14 | 160000.0 | 14 | 148000.0 | 13 | 109000.0 | 12 |
| 1947 | 378000.0 | 4 | 374000.0 | 4 | 362000.0 | 4 | 360000.0 | 2 | 351000.0 | 2 | 281000.0 | 2 | 274000.0 | 1 | 249000.0 | 1 | 188000.0 | 3 | 127000.0 | 6 |
| 1948 | 362000.0 | 6 | 359000.0 | 6 | 348000.0 | 6 | 316000.0 | 9 | 264000.0 | 10 | 215000.0 | 10 | 187000.0 | 11 | 156000.0 | 16 | 123000.0 | 18 | 82500.0 | 20 |
| 1949 | 218000.0 | 23 | 217000.0 | 21 | 211000.0 | 21 | 193000.0 | 22 | 178000.0 | 19 | 167000.0 | 19 | 146000.0 | 20 | 131000.0 | 23 | 111000.0 | 21 | 75200.0 | 22 |
| 1950 | 256000.0 | 13 | 252000.0 | 13 | 250000.0 | 13 | 242000.0 | 13 | 225000.0 | 12 | 208000.0 | 11 | 195000.0 | 10 | 186000.0 | 10 | 158000.0 | 10 | 106000.0 | 14 |
| 1951 | 330000.0 | 9 | 328000.0 | 9 | 323000.0 | 9 | 319000.0 | 7 | 316000.0 | 3 | 276000.0 | 4 | 237000.0 | 7 | 238000.0 | 2 | 208000.0 | 1 | 130000.0 | 3 |
| 1952 | 337000.0 | 7 | 337000.0 | 7 | 335000.0 | 7 | 321000.0 | 6 | 293000.0 | 8 | 258000.0 | 7 | 223000.0 | 9 | 200000.0 | 8 | 168000.0 | 8 | 130000.0 | 4 |
| 1953 | 232000.0 | 18 | 229000.0 | 18 | 217000.0 | 18 | 194000.0 | 21 | 172000.0 | 22 | 154000.0 | 20 | 141000.0 | 23 | 136000.0 | 21 | 124000.0 | 17 | 85300.0 | 16 |
| 1954 | 196000.0 | 27 | 195000.0 | 26 | 193000.0 | 24 | 183000.0 | 23 | 163000.0 | 24 | 152000.0 | 23 | 145000.0 | 21 | 133000.0 | 22 | 108000.0 | 22 | 72900.0 | 23 |
| 1955 | 207000.0 | 24 | 205000.0 | 24 | 200000.0 | 23 | 176000.0 | 25 | 151000.0 | 25 | 130000.0 | 26 | 126000.0 | 26 | 119000.0 | 25 | 103000.0 | 25 | 83300.0 | 19 |
| 1956 | 162000.0 | 30 | 152000.0 | 30 | 140000.0 | 30 | 136000.0 | 30 | 126000.0 | 30 | 110000.0 | 30 | 95500.0 | 30 | 87800.0 | 30 | 77600.0 | 29 | 57200.0 | 29 |
| 1957 | 174000.0 | 29 | 166000.0 | 29 | 147000.0 | 29 | 137000.0 | 29 | 135000.0 | 28 | 132000.0 | 25 | 130000.0 | 24 | 127000.0 | 24 | 105000.0 | 23 | 71200.0 | 26 |
| 1958 | 204000.0 | 25 | 201000.0 | 25 | 181000.0 | 26 | 156000.0 | 27 | 145000.0 | 27 | 127000.0 | 27 | 106000.0 | 28 | 96900.0 | 28 | 90000.0 | 27 | 68500.0 | 27 |
| 1959 | 219000.0 | 21 | 218000.0 | 20 | 214000.0 | 20 | 207000.0 | 18 | 181000.0 | 18 | 154000.0 | 21 | 142000.0 | 22 | 137000.0 | 20 | 113000.0 | 20 | 76000.0 | 21 |
| 1960 | 374000.0 | 5 | 371000.0 | 5 | 362000.0 | 5 | 338000.0 | 4 | 302000.0 | 5 | 278000.0 | 3 | 251000.0 | 4 | 224000.0 | 5 | 178000.0 | 5 | 127000.0 | 7 |
| 1961 | 245000.0 | 17 | 242000.0 | 17 | 232000.0 | 16 | 211000.0 | 15 | 184000.0 | 17 | 170000.0 | 17 | 158000.0 | 17 | 139000.0 | 18 | 115000.0 | 19 | 84000.0 | 18 |
| 1962 | 336000.0 | 8 | 334000.0 | 8 | 329000.0 | 8 | 316000.0 | 8 | 305000.0 | 4 | 254000.0 | 8 | 226000.0 | 8 | 199000.0 | 9 | 167000.0 | 9 | 129000.0 | 5 |
| 1963 | 177000.0 | 28 | 174000.0 | 28 | 164000.0 | 28 | 161000.0 | 26 | 150000.0 | 26 | 125000.0 | 28 | 120000.0 | 27 | 107000.0 | 27 | 87600.0 | 28 | 64600.0 | 28 |
| 1964 | 204000.0 | 26 | 193000.0 | 27 | 166000.0 | 27 | 150000.0 | 28 | 134000.0 | 29 | 116000.0 | 29 | 100000.0 | 29 | 88900.0 | 29 | 70800.0 | 30 | 51200.0 | 30 |
| 1965 | 380000.0 | 3 | 378000.0 | 3 | 376000.0 | 2 | 365000.0 | 1 | 359000.0 | 1 | 295000.0 | 1 | 252000.0 | 3 | 224000.0 | 6 | 176000.0 | 6 | 118000.0 | 8 |
| 1966 | 256000.0 | 14 | 243000.0 | 16 | 228000.0 | 17 | 211000.0 | 16 | 189000.0 | 16 | 185000.0 | 12 | 178000.0 | 12 | 166000.0 | 12 | 146000.0 | 14 | 111000.0 | 11 |
| 1967 | 264000.0 | 12 | 262000.0 | 12 | 258000.0 | 12 | 244000.0 | 12 | 223000.0 | 13 | 182000.0 | 15 | 165000.0 | 15 | 159000.0 | 15 | 128000.0 | 15 | 84900.0 | 17 |

APPENDIX 3 *(continued)* . . . .



## MISSISSIPPI RIVER AT ALTON, ILL. 05587500

DURATICN TABLE OF DAILY DISCHARGE FCR YEAR ENDING SEPTEMBER 30

| CLASS | CFS | TOTAL | ACCUM | PERCT | CLASS | CFS | TOTAL | ACCUM | PERCT | CLASS | CFS | TOTAL | ACCUM | PERCT | CLASS | CFS | TOTAL | ACCUM | PERCT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | C.CC | 0 | 11688 | 100.0 | 9 | 34000.00 | 550 | 10099 | 86.4 | 18 | 84000.0 | 406 | 4854 | 41.5 | 27 | 210000 | 221 | 836 | 7.1 |
| 1 | 15CC0.00 | 7 | 11688 | 100.C | 10 | 37C00.00 | 683 | 9549 | 81.7 | 19 | 92000.0 | 414 | 4448 | 38.1 | 28 | 230000 | 176 | 615 | 5.2 |
| 2 | 17CCC.C0 | 4 | 11681 | 99.9 | 11 | 41000.00 | 757 | 8866 | 75.9 | 20 | 100000.0 | 440 | 4034 | 34.5 | 29 | 250000 | 170 | 439 | 3.7 |
| 3 | 18CCC.00 | 17 | 11677 | 99.9 | 12 | 46000.00 | 511 | 8109 | 69.4 | 21 | 110000.0 | 880 | 3594 | 30.7 | 30 | 290000 | 101 | 269 | 2.3 |
| 4 | 2CCCC.00 | 77 | 11660 | 99.8 | 13 | 50000.00 | 612 | 7598 | 65.0 | 22 | 130000.0 | 372 | 2714 | 23.2 | 31 | 310000 | 91 | 168 | 1.4 |
| 5 | 22CCC.0C | 181 | 11583 | 99.1 | 14 | 56000.00 | 567 | 6986 | 59.8 | 23 | 140000.0 | 285 | 2342 | 20.0 | 32 | 340000 | 69 | 77 | .6 |
| 6 | 25CCC.00 | 274 | 114C2 | 97.6 | 15 | 62C00.00 | 487 | 6419 | 54.9 | 24 | 150000.0 | 447 | 2057 | 17.6 | 33 | 380000 | 6 | 8 | .0 |
| 7 | 28CC0.C0 | 271 | 11128 | 95.2 | 16 | 68C00.00 | 573 | 5932 | 50.8 | 25 | 170000.0 | 439 | 1610 | 13.8 | 34 | 420000 | 2 | 2 | .0 |
| 8 | 3CCC0.0C | 758 | 1CE57 | 92.9 | 17 | 76000.00 | 505 | 5359 | 45.9 | 26 | 190000.0 | 335 | 1171 | 10.0 | | | | | |

MISSOURI RIVER AT HERMANN, MO. 06934500

LOWEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

| YEAR | 1 | 3 | 7 | 14 | 30 | 60 | 90 | 120 | 183 | ANNUAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1930 | 15000.0 24 | 15000.0 19 | 15600.0 18 | 18700.0 20 | 20600.0 20 | 26200.0 23 | 30000.0 22 | 33200.0 23 | 33800.0 16 | 98100.0 33 |
| 1931 | 15800.0 26 | 15900.0 23 | 16700.0 21 | 17400.0 17 | 19100.0 16 | 22900.0 16 | 26800.0 17 | 29100.0 16 | 31100.0 12 | 47500.0 10 |
| 1932 | 17300.0 28 | 18400.0 29 | 20200.0 30 | 22900.0 31 | 26000.0 29 | 28900.0 28 | 32300.0 26 | 32400.0 22 | 39700.0 23 | 53400.0 14 |
| 1933 | 10700.0 8 | 11100.0 8 | 11400.0 5 | 15100.0 12 | 18100.0 12 | 22200.0 13 | 24100.0 11 | 27500.0 13 | 32400.0 14 | 55900.0 15 |
| 1934 | 12400.0 13 | 12800.0 13 | 13400.0 12 | 13800.0 8 | 15200.0 6 | 20300.0 10 | 21100.0 7 | 22500.0 7 | 27200.0 6 | 48100.0 11 |
| 1935 | 14400.0 21 | 15000.0 20 | 15300.0 17 | 16000.0 14 | 18800.0 15 | 21800.0 12 | 24300.0 12 | 25200.0 9 | 29300.0 11 | 37600.0 4 |
| 1936 | 9300.0 6 | 9770.0 5 | 11700.0 6 | 13400.0 6 | 15000.0 5 | 16400.0 5 | 23400.0 10 | 28700.0 15 | 28500.0 9 | 78500.0 25 |
| 1937 | 12600.0 15 | 13400.0 15 | 13800.0 13 | 16100.0 15 | 17400.0 11 | 20600.0 11 | 25900.0 16 | 28400.0 14 | 27800.0 8 | 45900.0 7 |
| 1938 | 8300.0 4 | 8430.0 3 | 8930.0 3 | 10300.0 3 | 12100.0 2 | 13500.0 2 | 15100.0 2 | 15200.0 2 | 19000.0 2 | 47000.0 9 |
| 1939 | 12600.0 16 | 13500.0 16 | 14600.0 16 | 17200.0 16 | 20100.0 18 | 22300.0 14 | 25300.0 14 | 27100.0 12 | 32400.0 15 | 62000.0 20 |
| 1940 | 4200.0 1 | 4200.0 1 | 4310.0 1 | 4810.0 1 | 6550.0 1 | 9030.0 1 | 11800.0 1 | 13000.0 1 | 15100.0 1 | 43300.0 6 |
| 1941 | 12200.0 12 | 12800.0 14 | 13900.0 14 | 15900.0 13 | 16600.0 9 | 17600.0 7 | 17900.0 6 | 19900.0 6 | 26700.0 5 | 35900.0 2 |
| 1942 | 14000.0 19 | 16400.0 25 | 18800.0 25 | 23200.0 32 | 31700.0 34 | 38800.0 33 | 51000.0 36 | 57100.0 36 | 67400.0 36 | 79000.0 26 |
| 1943 | 23200.0 35 | 24300.0 34 | 25400.0 35 | 27500.0 35 | 38100.0 36 | 43300.0 36 | 47100.0 34 | 54600.0 35 | 56300.0 33 | 87900.0 29 |
| 1944 | 17900.0 29 | 18100.0 27 | 18800.0 26 | 19100.0 21 | 19900.0 17 | 26800.0 25 | 29000.0 20 | 32100.0 21 | 35500.0 18 | 91200.0 32 |
| 1945 | 22900.0 34 | 24300.0 35 | 24900.0 34 | 26800.0 34 | 30700.0 33 | 36200.0 32 | 44000.0 33 | 44100.0 31 | 54400.0 32 | 109000.0 36 |
| 1946 | 10000.0 7 | 10500.0 6 | 11800.0 7 | 12800.0 5 | 18200.0 13 | 26500.0 24 | 34700.0 28 | 44800.0 32 | 50800.0 27 | 102000.0 34 |
| 1947 | 12800.0 17 | 15000.0 21 | 17000.0 23 | 21000.0 26 | 26100.0 30 | 27900.0 26 | 33000.0 27 | 38200.0 28 | 51000.0 28 | 61600.0 19 |
| 1948 | 18000.0 30 | 18800.0 30 | 20400.0 31 | 21500.0 29 | 24200.0 27 | 28200.0 27 | 32200.0 25 | 37600.0 27 | 40800.0 25 | 109000.0 37 |
| 1949 | 19500.0 32 | 19600.0 32 | 20700.0 32 | 22100.0 30 | 24400.0 28 | 34100.0 31 | 40100.0 30 | 41200.0 30 | 52300.0 30 | 89500.0 30 |
| 1950 | 24900.0 37 | 27400.0 37 | 29300.0 37 | 31300.0 36 | 32500.0 35. | 42000.0 35 | 50300.0 35 | 52900.0 34 | 59300.0 35 | 83600.0 27 |
| 1951 | 11000.0 9 | 12300.0 11 | 14600.0 15 | 19400.0 23 | 23900.0 26 | 25800.0 21 | 30200.0 23 | 36600.0 25 | 52200.0 29 | 90400.0 31 |
| 1952 | 23500.0 36 | 24300.0 36 | 27200.0 36 | 34400.0 37 | 41400.0 38 | 53800.0 38 | 66400.0 37 | 79000.0 38 | 93300.0 38 | 158000.0 38 |
| 1953 | 18900.0 31 | 19000.0 31 | 19600.0 28 | 21200.0 28 | 23500.0 25 | 25000.0 19 | 29700.0 21 | 32000.0 20 | 36100.0 20 | 76800.0 24 |
| 1954 | 12500.0 14 | 12800.0 12 | 13200.0 11 | 14000.0 10 | 16300.0 8 | 18800.0 8 | 21700.0 8 | 24500.0 8 | 28800.0 10 | 49600.0 13 |
| 1955 | 17000.0 27 | 18300.0 28 | 20100.0 29 | 21000.0 27 | 23100.0 22 | 25700.0 20 | 27400.0 18 | 30400.0 19 | 36800.0 21 | 49100.0 12 |
| 1956 | 11800.0 11 | 12100.0 10 | 12300.0 9 | 14200.0 11 | 15300.0 7 | 16700.0 6 | 17300.0 5 | 18200.0 3 | 27500.0 7 | 38100.0 5 |
| 1957 | 9000.0 5 | 10700.0 7 | 12200.0 8 | 13900.0 9 | 14900.0 4 | 16200.0 3 | 17100.0 3 | 18400.0 4 | 22800.0 3 | 32800.0 1 |
| 1958 | 15000.0 22 | 16300.0 24 | 17300.0 24 | 20800.0 24 | 23400.0 23 | 26100.0 22 | 28400.0 19 | 30200.0 17 | 35100.0 17 | 58500.0 17 |
| 1959 | 12800.0 18 | 13500.0 17 | 15700.0 19 | 17800.0 19 | 20400.0 19 | 23900.0 18 | 30400.0 24 | 34100.0 24 | 45600.0 26 | 73400.0 22 |
| 1960 | 21400.0 33 | 22000.0 33 | 24100.0 33 | 25600.0 33 | 26200.0 31 | 32500.0 30 | 40300.0 31 | 41000.0 29 | 52400.0 31 | 62300.0 21 |
| 1961 | 11000.0 10 | 11200.0 9 | 12400.0 10 | 13800.0 7 | 18500.0 14 | 22500.0 15 | 25400.0 15 | 30300.0 18 | 35600.0 19 | 74100.0 23 |
| 1962 | 28800.0 38 | 30500.0 38 | 34800.0 38 | 36200.0 38 | 39900.0 37 | 43500.0 37 | 68800.0 38 | 75500.0 37 | 83900.0 37 | 103000.0 35 |
| 1963 | 7530.0 3 | 8510.0 4 | 9290.0 4 | 11500.0 4 | 16700.0 10 | 19300.0 9 | 22000.0 9 | 26900.0 11 | 37500.0 22 | 57900.0 16 |
| 1964 | 6210.0 2 | 6490.0 2 | 7400.0 2 | 9360.0 2 | 14000.0 3 | 16300.0 4 | 17200.0 4 | 19000.0 5 | 25400.0 4 | 37500.0 3 |
| 1965 | 15400.0 25 | 17000.0 26 | 18900.0 27 | 20800.0 25 | 23500.0 24 | 32000.0 29 | 35000.0 29 | 36800.0 26 | 39800.0 24 | 58800.0 18 |
| 1966 | 15000.0 23 | 15900.0 22 | 16200.0 20 | 17500.0 18 | 30100.0 32 | 41000.0 34 | 43900.0 32 | 50400.0 33 | 58700.0 34 | 85100.0 28 |
| 1967 | 14300.0 20 | 14800.0 18 | 16900.0 22 | 19100.0 22 | 20700.0 21 | 23800.0 17 | 24300.0 13 | 26200.0 10 | 31500.0 13 | 46700.0 8 |

MISSOURI RIVER AT HERMANN, MO. 06934500

HIGHEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

| YEAR | 1 | | 3 | | 7 | | 15 | | 30 | | 60 | | 90 | | 120 | | 183 | | ANNUAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1929 | 407000.0 | 7 | 401000.0 | 7 | 377000.0 | 6 | 309000.0 | 9 | 273000.0 | 6 | 253000.0 | 3 | 237000.0 | 3 | 217000.0 | 2 | 171000.0 | 2 | 114000.0 | 2 |
| 1930 | 164000.0 | 32 | 151000.0 | 32 | 149000.0 | 29 | 137000.0 | 27 | 109000.0 | 28 | 97800.0 | 25 | 86900.0 | 28 | 83800.0 | 26 | 75600.0 | 24 | 55400.0 | 25 |
| 1931 | 121000.0 | 37 | 94700.0 | 38 | 77500.0 | 38 | 61200.0 | 38 | 58300.0 | 37 | 54400.0 | 36 | 51900.0 | 36 | 49300.0 | 36 | 44200.0 | 37 | 37100.0 | 36 |
| 1932 | 267000.0 | 17 | 262000.0 | 17 | 233000.0 | 17 | 185000.0 | 19 | 135000.0 | 20 | 114000.0 | 21 | 97900.0 | 20 | 91400.0 | 21 | 81700.0 | 21 | 70300.0 | 18 |
| 1933 | 178000.0 | 29 | 168000.0 | 28 | 157000.0 | 26 | 145000.0 | 25 | 128000.0 | 21 | 103000.0 | 23 | 91000.0 | 24 | 86100.0 | 23 | 70900.0 | 27 | 51900.0 | 28 |
| 1934 | 82000.0 | 39 | 70600.0 | 39 | 58000.0 | 39 | 48000.0 | 39 | 46800.0 | 39 | 41000.0 | 39 | 38000.0 | 39 | 38900.0 | 39 | 35600.0 | 39 | 29800.0 | 39 |
| 1935 | 454000.0 | 5 | 450000.0 | 5 | 434000.0 | 5 | 389000.0 | 4 | 322000.0 | 4 | 247000.0 | 5 | 194000.0 | 7 | 159000.0 | 8 | 124000.0 | 10 | 80000.0 | 13 |
| 1936 | 140000.0 | 34 | 133000.0 | 33 | 118000.0 | 33 | 105000.0 | 31 | 96800.0 | 30 | 78400.0 | 32 | 71500.0 | 32 | 67600.0 | 32 | 54500.0 | 34 | 41100.0 | 34 |
| 1937 | 185000.0 | 27 | 171000.0 | 27 | 154000.0 | 28 | 137000.0 | 26 | 115000.0 | 27 | 98100.0 | 24 | 91200.0 | 23 | 85700.0 | 25 | 84300.0 | 20 | 59000.0 | 22 |
| 1938 | 229000.0 | 22 | 224000.0 | 22 | 201000.0 | 21 | 161000.0 | 22 | 142000.0 | 19 | 120000.0 | 19 | 110000.0 | 19 | 106000.0 | 18 | 89000.0 | 19 | 56600.0 | 24 |
| 1939 | 244000.0 | 20 | 232000.0 | 20 | 199000.0 | 22 | 166000.0 | 21 | 127000.0 | 22 | 105000.0 | 22 | 94900.0 | 21 | 93700.0 | 20 | 78400.0 | 22 | 53200.0 | 27 |
| 1940 | 107000.0 | 38 | 99100.0 | 37 | 83600.0 | 37 | 68600.0 | 37 | 60000.0 | 36 | 53400.0 | 37 | 50900.0 | 37 | 48100.0 | 37 | 45600.0 | 36 | 31000.0 | 38 |
| 1941 | 250000.0 | 19 | 249000.0 | 18 | 223000.0 | 19 | 159000.0 | 23 | 121000.0 | 25 | 85600.0 | 29 | 89600.0 | 26 | 76800.0 | 30 | 67400.0 | 30 | 47400.0 | 29 |
| 1942 | 425000.0 | 6 | 408000.0 | 6 | 368000.0 | 8 | 322000.0 | 6 | 247000.0 | 9 | 204000.0 | 9 | 169000.0 | 9 | 149000.0 | 9 | 122000.0 | 11 | 105000.0 | 5 |
| 1943 | 544000.0 | 3 | 519000.0 | 3 | 470000.0 | 2 | 353000.0 | 5 | 274000.0 | 5 | 253000.0 | 4 | 207000.0 | 5 | 182000.0 | 5 | 139000.0 | 6 | 96500.0 | 7 |
| 1944 | 565000.0 | 2 | 525000.0 | 2 | 464000.0 | 3 | 390000.0 | 3 | 330000.0 | 3 | 222000.0 | 6 | 202000.0 | 6 | 180000.0 | 6 | 152000.0 | 5 | 95900.0 | 8 |
| 1945 | 396000.0 | 9 | 389000.0 | 8 | 370000.0 | 7 | 301000.0 | 10 | 244000.0 | 10 | 217000.0 | 7 | 217000.0 | 4 | 209000.0 | 4 | 170000.0 | 3 | 110000.0 | 3 |
| 1946 | 202000.0 | 23 | 191000.0 | 24 | 170000.0 | 25 | 123000.0 | 29 | 88700.0 | 31 | 80800.0 | 31 | 77200.0 | 30 | 77200.0 | 29 | 74400.0 | 25 | 61900.0 | 20 |
| 1947 | 484000.0 | 4 | 478000.0 | 4 | 460000.0 | 4 | 409000.0 | 2 | 352000.0 | 2 | 260000.0 | 2 | 239000.0 | 2 | 216000.0 | 3 | 165000.0 | 4 | 108000.0 | 4 |
| 1948 | 330000.0 | 13 | 322000.0 | 14 | 298000.0 | 14 | 257000.0 | 14 | 184000.0 | 14 | 163000.0 | 14 | 131000.0 | 15 | 121000.0 | 15 | 118000.0 | 12 | 79900.0 | 14 |
| 1949 | 235000.0 | 21 | 228000.0 | 21 | 207000.0 | 20 | 198000.0 | 17 | 177000.0 | 15 | 166000.0 | 12 | 146000.0 | 12 | 142000.0 | 10 | 135000.0 | 7 | 92700.0 | 9 |
| 1950 | 263000.0 | 18 | 248000.0 | 19 | 224000.0 | 18 | 187000.0 | 18 | 155000.0 | 18 | 146000.0 | 16 | 141000.0 | 13 | 138000.0 | 11 | 125000.0 | 9 | 92200.0 | 10 |
| 1951 | 615000.0 | 1 | 600000.0 | 1 | 554000.0 | 1 | 523000.0 | 1 | 481000.0 | 1 | 344000.0 | 1 | 283000.0 | 1 | 257000.0 | 1 | 223000.0 | 1 | 139000.0 | 1 |
| 1952 | 366000.0 | 11 | 362000.0 | 11 | 347000.0 | 10 | 310000.0 | 8 | 272000.0 | 7 | 216000.0 | 8 | 181000.0 | 8 | 160000.0 | 7 | 133000.0 | 8 | 103000.0 | 6 |
| 1953 | 174000.0 | 31 | 165000.0 | 31 | 140000.0 | 30 | 116000.0 | 30 | 102000.0 | 29 | 96300.0 | 26 | 89000.0 | 27 | 89500.0 | 22 | 75700.0 | 23 | 55300.0 | 26 |
| 1954 | 142000.0 | 33 | 131000.0 | 34 | 107000.0 | 35 | 86000.0 | 35 | 84000.0 | 34 | 68700.0 | 34 | 60600.0 | 35 | 57900.0 | 35 | 52900.0 | 35 | 40800.0 | 35 |
| 1955 | 178000.0 | 30 | 167000.0 | 29 | 136000.0 | 32 | 104000.0 | 32 | 88100.0 | 32 | 75600.0 | 33 | 67000.0 | 33 | 64200.0 | 33 | 58900.0 | 32 | 47200.0 | 31 |
| 1956 | 139000.0 | 35 | 125000.0 | 36 | 98000.0 | 36 | 75000.0 | 36 | 58100.0 | 38 | 49200.0 | 38 | 47200.0 | 38 | 46100.0 | 38 | 42900.0 | 38 | 35100.0 | 37 |
| 1957 | 192000.0 | 25 | 186000.0 | 25 | 176000.0 | 24 | 155000.0 | 24 | 123000.0 | 24 | 114000.0 | 20 | 94000.0 | 22 | 86000.0 | 24 | 70900.0 | 28 | 47000.0 | 32 |
| 1958 | 337000.0 | 12 | 331000.0 | 12 | 310000.0 | 13 | 269000.0 | 13 | 240000.0 | 11 | 162000.0 | 15 | 131000.0 | 16 | 115000.0 | 17 | 106000.0 | 16 | 73500.0 | 17 |
| 1959 | 189000.0 | 26 | 180000.0 | 26 | 156000.0 | 27 | 127000.0 | 28 | 118000.0 | 26 | 93400.0 | 28 | 86300.0 | 29 | 82700.0 | 27 | 74200.0 | 26 | 57100.0 | 23 |
| 1960 | 328000.0 | 14 | 326000.0 | 13 | 317000.0 | 12 | 285000.0 | 11 | 232000.0 | 12 | 186000.0 | 10 | 150000.0 | 10 | 135000.0 | 12 | 107000.0 | 15 | 79200.0 | 15 |
| 1961 | 401000.0 | 8 | 389000.0 | 9 | 351000.0 | 9 | 274000.0 | 12 | 201000.0 | 13 | 164000.0 | 13 | 148000.0 | 11 | 129000.0 | 13 | 113000.0 | 13 | 79200.0 | 16 |
| 1962 | 275000.0 | 16 | 267000.0 | 15 | 247000.0 | 16 | 223000.0 | 15 | 171000.0 | 16 | 132000.0 | 17 | 120000.0 | 17 | 105000.0 | 19 | 100000.0 | 18 | 84900.0 | 11 |
| 1963 | 134000.0 | 36 | 130000.0 | 35 | 110000.0 | 34 | 94100.0 | 34 | 76600.0 | 35 | 64300.0 | 35 | 65700.0 | 34 | 61900.0 | 34 | 55300.0 | 33 | 45000.0 | 33 |
| 1964 | 199000.0 | 24 | 194000.0 | 23 | 179000.0 | 23 | 174000.0 | 20 | 124000.0 | 23 | 96000.0 | 27 | 90000.0 | 25 | 81700.0 | 28 | 69400.0 | 29 | 47400.0 | 30 |
| 1965 | 304000.0 | 15 | 300000.0 | 15 | 273000.0 | 15 | 198000.0 | 16 | 159000.0 | 17 | 131000.0 | 18 | 120000.0 | 18 | 119000.0 | 16 | 112000.0 | 14 | 80100.0 | 12 |
| 1966 | 182000.0 | 28 | 165000.0 | 30 | 139000.0 | 31 | 104000.0 | 33 | 87300.0 | 33 | 83300.0 | 30 | 75300.0 | 31 | 69900.0 | 31 | 67300.0 | 31 | 59800.0 | 21 |
| 1967 | 367000.0 | 10 | 363000.0 | 10 | 345000.0 | 11 | 315000.0 | 7 | 255000.0 | 8 | 174000.0 | 11 | 141000.0 | 14 | 125000.0 | 14 | 101000.0 | 17 | 66500.0 | 19 |

MISSOURI RIVER AT HERMANN, MO. 06934500

DURATION TABLE OF DAILY DISCHARGE FOR YEAR ENDING SEPTEMBER 30

CFS_DAYS
24258100.0

| CLASS | CFS | TOTAL | ACCUM | PERCT | CLASS | CFS | TOTAL | ACCUM | PERCT | CLASS | CFS | TOTAL | ACCUM | PERCT | CLASS | CFS | TOTAL | ACCUM | PERCT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00 | 0 | 14244 | 100.0 | 9 | 14000.00 | 214 | 14024 | 98.5 | 18 | 54000.0 | 1227 | 6277 | 44.1 | 27 | 210000 | 178 | 609 | 4.2 |
| 1 | 4200.00 | 8 | 14244 | 100.0 | 10 | 16000.00 | 479 | 13810 | 97.0 | 19 | 63000.0 | 898 | 5050 | 35.5 | 28 | 240000 | 180 | 431 | 3.0 |
| 2 | 4900.00 | 5 | 14236 | 99.9 | 11 | 19000.00 | 552 | 13331 | 93.6 | 20 | 73000.0 | 768 | 4152 | 29.1 | 29 | 280000 | 122 | 251 | 1.7 |
| 3 | 5700.00 | 6 | 14231 | 99.9 | 12 | 22000.00 | 728 | 12779 | 89.7 | 21 | 85000.0 | 773 | 3384 | 23.8 | 30 | 330000 | 55 | 129 | .9 |
| 4 | 6600.00 | 7 | 14225 | 99.9 | 13 | 26000.00 | 746 | 12051 | 84.6 | 22 | 99000.0 | 698 | 2611 | 18.3 | 31 | 380000 | 39 | 74 | .5 |
| 5 | 7700.00 | 10 | 14218 | 99.8 | 14 | 30000.00 | 864 | 11305 | 79.4 | 23 | 120000.0 | 229 | 1913 | 13.4 | 32 | 450000 | 28 | 35 | .2 |
| 6 | 8900.00 | 30 | 14208 | 99.7 | 15 | 35000.00 | 1284 | 10441 | 73.3 | 24 | 130000.0 | 570 | 1684 | 11.8 | 33 | 520000 | 5 | 7 | .0 |
| 7 | 10000.00 | 38 | 14178 | 99.5 | 16 | 40000.00 | 1634 | 9157 | 64.3 | 25 | 160000.0 | 261 | 1114 | 7.8 | 34 | 600000 | 2 | 2 | .0 |
| 8 | 12000.00 | 116 | 14140 | 99.3 | 17 | 47000.00 | 1246 | 7523 | 52.8 | 26 | 180000.0 | 244 | 853 | 6.0 | | | | | |

## MISSISSIPPI RIVER AT ST. LOUIS, MO. 07010000

LOWEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

| YEAR | 1 | 3 | 7 | 14 | 30 | 60 | 90 | 120 | 183 | ANNUAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1934 | 35200.0 4 | 36600.0 4 | 40100.0 5 | 41800.0 6 | 44200.0 5 | 50700.0 5 | 52100.0 4 | 54100.0 4 | 59600.0 4 | 120000.0 7 |
| 1935 | 39800.0 7 | 40500.0 7 | 42600.0 7 | 45200.0 7 | 50200.0 8 | 56700.0 13 | 62200.0 11 | 64100.0 9 | 68600.0 8 | 100000.0 5 |
| 1936 | 43800.0 10 | 44100.0 8 | 46600.0 9 | 50600.0 14 | 51300.0 10 | 55000.0 8 | 67000.0 12 | 77800.0 17 | 76400.0 11 | 179000.0 24 |
| 1937 | 39700.0 6 | 39900.0 6 | 40400.0 6 | 41200.0 5 | 43000.0 4 | 49300.0 4 | 60200.0 10 | 70900.0 12 | 71400.0 9 | 125000.0 10 |
| 1938 | 27800.0 1 | 28200.0 2 | 29800.0 2 | 34700.0 2 | 40900.0 3 | 45900.0 3 | 47200.0 2 | 48100.0 2 | 57900.0 2 | 124000.0 8 |
| 1939 | 49100.0 18 | 51900.0 19 | 56700.0 20 | 58800.0 19 | 65400.0 21 | 75800.0 24 | 85200.0 24 | 91300.0 24 | 114000.0 25 | 177000.0 22 |
| 1940 | 28000.0 2 | 28100.0 1 | 28200.0 1 | 28700.0 1 | 30900.0 1 | 35700.0 1 | 41000.0 1 | 42600.0 1 | 45100.0 1 | 110000.0 6 |
| 1941 | 46500.0 15 | 47200.0 14 | 48000.0 12 | 48900.0 9 | 49600.0 7 | 51600.0 6 | 56200.0 6 | 61400.0 7 | 71700.0 10 | 92700.0 3 |
| 1942 | 57100.0 22 | 57800.0 22 | 59200.0 22 | 60200.0 21 | 62200.0 18 | 80000.0 25 | 113000.0 31 | 129000.0 31 | 161000.0 33 | 191000.0 28 |
| 1943 | 76200.0 33 | 78100.0 33 | 79500.0 33 | 84000.0 34 | 108000.0 35 | 125000.0 34 | 136000.0 34 | 142000.0 33 | 153000.0 32 | 206000.0 29 |
| 1944 | 66700.0 27 | 66700.0 26 | 66800.0 26 | 67000.0 25 | 67700.0 22 | 71400.0 18 | 75300.0 19 | 81600.0 20 | 87300.0 18 | 210000.0 30 |
| 1945 | 69000.0 29 | 69000.0 29 | 69200.0 28 | 69500.0 27 | 70700.0 26 | 73700.0 21 | 82900.0 23 | 84100.0 22 | 103000.0 23 | 221000.0 32 |
| 1946 | 69000.0 30 | 70300.0 30 | 71200.0 30 | 71700.0 28 | 76600.0 28 | 89300.0 28 | 98000.0 28 | 116000.0 28 | 132000.0 30 | 240000.0 35 |
| 1947 | 70100.0 31 | 72200.0 32 | 73000.0 31 | 76100.0 30 | 88700.0 30 | 91900.0 29 | 97500.0 27 | 108000.0 27 | 127000.0 28 | 157000.0 17 |
| 1948 | 41500.0 8 | 44100.0 9 | 47600.0 10 | 50200.0 10 | 58500.0 15 | 70400.0 16 | 80600.0 22 | 84800.0 23 | 87100.0 17 | 237000.0 34 |
| 1949 | 52100.0 20 | 53800.0 20 | 55500.0 19 | 58000.0 17 | 62300.0 19 | 72100.0 19 | 74200.0 18 | 74300.0 15 | 95100.0 22 | 171000.0 20 |
| 1950 | 57900.0 23 | 59600.0 23 | 62600.0 24 | 63100.0 23 | 67900.0 25 | 86800.0 27 | 91700.0 26 | 96000.0 25 | 115000.0 26 | 165000.0 19 |
| 1951 | 42300.0 9 | 44800.0 10 | 50200.0 16 | 56900.0 16 | 60000.0 16 | 65900.0 15 | 69400.0 15 | 73200.0 13 | 92500.0 21 | 188000.0 26 |
| 1952 | 80600.0 36 | 82100.0 36 | 85900.0 35 | 89800.0 35 | 112000.0 36 | 144000.0 36 | 162000.0 36 | 180000.0 36 | 199000.0 36 | 307000.0 36 |
| 1953 | 58000.0 24 | 59800.0 24 | 61900.0 23 | 63700.0 24 | 67800.0 24 | 70600.0 17 | 74100.0 17 | 73700.0 14 | 85500.0 14 | 180000.0 25 |
| 1954 | 45500.0 14 | 47900.0 15 | 49000.0 13 | 50400.0 12 | 52400.0 11 | 55600.0 11 | 59800.0 8 | 61900.0 8 | 66000.0 6 | 125000.0 9 |
| 1955 | 64600.0 25 | 65400.0 25 | 66600.0 25 | 67200.0 26 | 71800.0 27 | 84500.0 26 | 87900.0 25 | 97300.0 26 | 109000.0 24 | 144000.0 14 |
| 1956 | 44400.0 11 | 44800.0 11 | 46000.0 8 | 47100.0 8 | 50800.0 9 | 52000.0 7 | 52900.0 5 | 57300.0 6 | 67700.0 7 | 100000.0 4 |
| 1957 | 45000.0 13 | 45700.0 13 | 47800.0 11 | 51400.0 15 | 54800.0 13 | 55500.0 10 | 56400.0 7 | 57100.0 5 | 61800.0 5 | 91700.0 2 |
| 1958 | 55400.0 21 | 56500.0 21 | 57300.0 21 | 61100.0 22 | 67700.0 23 | 74300.0 22 | 79600.0 21 | 82700.0 21 | 85600.0 15 | 142000.0 13 |
| 1959 | 47600.0 16 | 48300.0 16 | 49100.0 14 | 50400.0 13 | 53400.0 12 | 56200.0 12 | 67000.0 13 | 70700.0 11 | 87700.0 19 | 149000.0 15 |
| 1960 | 65800.0 26 | 67000.0 27 | 68700.0 27 | 77100.0 31 | 90400.0 31 | 101000.0 31 | 112000.0 30 | 122000.0 29 | 127000.0 29 | 155000.0 16 |
| 1961 | 49000.0 17 | 49000.0 17 | 49300.0 15 | 50200.0 11 | 54900.0 14 | 60200.0 14 | 67300.0 14 | 77000.0 16 | 87000.0 16 | 191000.0 27 |
| 1962 | 77000.0 34 | 78900.0 34 | 82100.0 34 | 83100.0 33 | 96900.0 32 | 120000.0 32 | 133000.0 32 | 158000.0 35 | 181000.0 35 | 218000.0 31 |
| 1963 | 35800.0 5 | 37100.0 5 | 38400.0 4 | 40900.0 4 | 48600.0 6 | 55200.0 9 | 60100.0 9 | 67700.0 10 | 90000.0 20 | 163000.0 18 |
| 1964 | 34600.0 3 | 35400.0 3 | 36400.0 3 | 37200.0 3 | 39800.0 2 | 45500.0 2 | 47700.0 3 | 52800.0 3 | 58000.0 3 | 91500.0 1 |
| 1965 | 50600.0 19 | 50600.0 18 | 52700.0 18 | 58800.0 20 | 60800.0 17 | 72100.0 20 | 71700.0 16 | 80300.0 19 | 81300.0 12 | 129000.0 11 |
| 1966 | 70600.0 32 | 71500.0 31 | 73200.0 32 | 77600.0 32 | 104000.0 33 | 135000.0 35 | 135000.0 33 | 144000.0 34 | 175000.0 34 | 226000.0 33 |
| 1967 | 44700.0 12 | 45600.0 12 | 52300.0 17 | 58200.0 18 | 63300.0 20 | 75500.0 23 | 77500.0 20 | 78200.0 18 | 82000.0 13 | 132000.0 12 |
| 1968 | 67700.0 28 | 68200.0 28 | 69600.0 29 | 73500.0 29 | 87100.0 29 | 94700.0 30 | 107000.0 29 | 122000.0 30 | 126000.0 27 | 179000.0 23 |
| 1969 | 77200.0 35 | 81200.0 35 | 88400.0 36 | 93500.0 36 | 106000.0 34 | 123000.0 33 | 138000.0 35 | 138000.0 32 | 149000.0 31 | 177000.0 21 |

## MISSISSIPPI RIVER AT ST. LOUIS, MO. 07010000

HIGHEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

| YEAR | 1 | 3 | 7 | 15 | 30 | 60 | 90 | 120 | 183 | ANNUAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1934 | 136000.0 36 | 134000.0 36 | 131000.0 36 | 124000.0 36 | 112000.0 36 | 98400.0 36 | 90100.0 36 | 85400.0 36 | 78800.0 36 | 67700.0 36 |
| 1935 | 649000.0 8 | 641000.0 8 | 621000.0 7 | 560000.0 7 | 486000.0 8 | 428000.0 8 | 364000.0 9 | 325000.0 10 | 274000.0 10 | 188000.0 13 |
| 1936 | 332000.0 29 | 326000.0 29 | 292000.0 29 | 274000.0 28 | 268000.0 24 | 240000.0 25 | 223000.0 27 | 201000.0 27 | 154000.0 31 | 114000.0 31 |
| 1937 | 372000.0 24 | 365000.0 24 | 330000.0 25 | 299000.0 24 | 264000.0 27 | 235000.0 26 | 233000.0 25 | 231000.0 22 | 209000.0 21 | 147000.0 23 |
| 1938 | 431000.0 21 | 426000.0 21 | 401000.0 21 | 357000.0 21 | 343000.0 18 | 293000.0 19 | 279000.0 18 | 268000.0 16 | 231000.0 16 | 157000.0 19 |
| 1939 | 529000.0 15 | 514000.0 16 | 473000.0 17 | 396000.0 17 | 332000.0 20 | 302000.0 18 | 252000.0 20 | 242000.0 19 | 202000.0 22 | 148000.0 22 |
| 1940 | 184000.0 35 | 178000.0 35 | 164000.0 35 | 145000.0 35 | 136000.0 35 | 125000.0 35 | 127000.0 35 | 119000.0 35 | 111000.0 35 | 79100.0 35 |
| 1941 | 451000.0 20 | 446000.0 20 | 422000.0 20 | 344000.0 22 | 267000.0 25 | 212000.0 30 | 210000.0 28 | 192000.0 29 | 161000.0 28 | 120000.0 29 |
| 1942 | 663000.0 7 | 649000.0 7 | 608000.0 8 | 539000.0 10 | 459000.0 11 | 375000.0 12 | 323000.0 13 | 308000.0 11 | 270000.0 13 | 236000.0 4 |
| 1943 | 833000.0 2 | 820000.0 2 | 786000.0 2 | 670000.0 4 | 557000.0 4 | 516000.0 3 | 445000.0 5 | 400000.0 5 | 323000.0 6 | 235000.0 5 |
| 1944 | 834000.0 1 | 829000.0 1 | 789000.0 1 | 711000.0 3 | 611000.0 3 | 487000.0 4 | 449000.0 4 | 404000.0 4 | 326000.0 5 | 209000.0 9 |
| 1945 | 610000.0 11 | 608000.0 11 | 591000.0 11 | 547000.0 9 | 508000.0 7 | 449000.0 7 | 458000.0 3 | 434000.0 [illegible] | 347000.0 3 | 223000.0 7 |
| 1946 | 500000.0 18 | 494000.0 18 | 468000.0 18 | 387000.0 19 | 327000.0 21 | 261000.0 22 | 245000.0 21 | 234000.0 21 | 224000.0 19 | 173000.0 15 |
| 1947 | 783000.0 3 | 777000.0 3 | 765000.0 3 | 736000.0 1 | 687000.0 1 | 531000.0 1 | 510000.0 1 | 463000.0 2 | 350000.0 2 | 237000.0 3 |
| 1948 | 629000.0 9 | 622000.0 9 | 597000.0 9 | 529000.0 12 | 427000.0 14 | 339000.0 14 | 296000.0 16 | 263000.0 18 | 241000.0 15 | 163000.0 18 |
| 1949 | 422000.0 22 | 418000.0 22 | 394000.0 22 | 363000.0 20 | 339000.0 19 | 332000.0 16 | 292000.0 17 | 267000.0 17 | 247000.0 14 | 170000.0 16 |
| 1950 | 461000.0 19 | 449000.0 19 | 429000.0 19 | 396000.0 18 | 378000.0 16 | 351000.0 13 | 333000.0 12 | 308000.0 12 | 271000.0 12 | 199000.0 11 |
| 1951 | 779000.0 4 | 772000.0 4 | 754000.0 4 | 719000.0 2 | 664000.0 2 | 522000.0 2 | 485000.0 2 | 475000.0 1 | 408000.0 1 | 265000.0 1 |
| 1952 | 682000.0 5 | 679000.0 5 | 664000.0 5 | 612000.0 5 | 548000.0 5 | 467000.0 5 | 403000.0 6 | 358000.0 8 | 301000.0 7 | 233000.0 6 |
| 1953 | 367000.0 25 | 361000.0 25 | 334000.0 24 | 296000.0 26 | 265000.0 26 | 250000.0 24 | 230000.0 26 | 226000.0 23 | 200000.0 23 | 141000.0 25 |
| 1954 | 289000.0 33 | 277000.0 33 | 258000.0 33 | 234000.0 33 | 226000.0 30 | 218000.0 28 | 206000.0 30 | 188000.0 30 | 160000.0 29 | 114000.0 30 |
| 1955 | 309000.0 30 | 295000.0 30 | 269000.0 31 | 237000.0 32 | 210000.0 33 | 194000.0 31 | 192000.0 31 | 182000.0 31 | 159000.0 30 | 130000.0 27 |
| 1956 | 225000.0 34 | 206000.0 34 | 183000.0 34 | 174000.0 34 | 165000.0 34 | 151000.0 34 | 138000.0 34 | 133000.0 34 | 120000.0 34 | 94000.0 34 |
| 1957 | 338000.0 28 | 329000.0 28 | 327000.0 26 | 299000.0 23 | 272000.0 23 | 255000.0 23 | 234000.0 23 | 223000.0 25 | 182000.0 26 | 123000.0 28 |
| 1958 | 504000.0 17 | 499000.0 17 | 477000.0 16 | 431000.0 16 | 385000.0 15 | 292000.0 20 | 240000.0 22 | 215000.0 26 | 200000.0 24 | 145000.0 24 |
| 1959 | 362000.0 26 | 348000.0 26 | 311000.0 28 | 290000.0 27 | 254000.0 28 | 230000.0 27 | 233000.0 24 | 225000.0 24 | 191000.0 25 | 136000.0 26 |
| 1960 | 667000.0 6 | 663000.0 6 | 648000.0 6 | 609000.0 6 | 528000.0 6 | 460000.0 6 | 403000.0 7 | 361000.0 7 | 285000.0 8 | 208000.0 10 |
| 1961 | 588000.0 12 | 578000.0 13 | 543000.0 13 | 449000.0 15 | 368000.0 17 | 335000.0 15 | 312000.0 14 | 274000.0 15 | 228000.0 17 | 167000.0 17 |
| 1962 | 588000.0 13 | 583000.0 12 | 568000.0 12 | 535000.0 11 | 476000.0 10 | 379000.0 11 | 341000.0 11 | 308000.0 13 | 273000.0 11 | 219000.0 8 |
| 1963 | 299000.0 32 | 291000.0 32 | 258000.0 32 | 240000.0 31 | 230000.0 29 | 189000.0 33 | 189000.0 33 | 174000.0 32 | 147000.0 32 | 113000.0 32 |
| 1964 | 306000.0 31 | 293000.0 31 | 277000.0 30 | 252000.0 30 | 212000.0 32 | 191000.0 32 | 190000.0 32 | 168000.0 33 | 140000.0 33 | 99600.0 33 |
| 1965 | 549000.0 14 | 544000.0 14 | 518000.0 14 | 498000.0 14 | 458000.0 12 | 389000.0 10 | 353000.0 10 | 328000.0 9 | 278000.0 9 | 198000.0 12 |
| 1966 | 410000.0 23 | 365000.0 23 | 342000.0 23 | 297000.0 25 | 275000.0 22 | 263000.0 21 | 253000.0 19 | 237000.0 20 | 213000.0 20 | 174000.0 14 |
| 1967 | 528000.0 16 | 525000.0 15 | 518000.0 15 | 503000.0 13 | 435000.0 13 | 315000.0 17 | 305000.0 15 | 285000.0 14 | 228000.0 18 | 156000.0 20 |
| 1968 | 344000.0 27 | 339000.0 27 | 312000.0 27 | 273000.0 29 | 218000.0 31 | 214000.0 29 | 210000.0 29 | 200000.0 28 | 175000.0 27 | 156000.0 21 |
| 1969 | 616000.0 10 | 613000.0 10 | 596000.0 10 | 558000.0 8 | 477000.0 9 | 398000.0 9 | 382000.0 8 | 383000.0 6 | 330000.0 4 | 243000.0 2 |

## MISSISSIPPI RIVER AT ST. LOUIS, MO. 07010000

DURATION TABLE OF DAILY DISCHARGE FOR YEAR ENDING SEPTEMBER 30

| CLASS | CFS | TOTAL | ACCUM | PERCT | CLASS | CFS | TOTAL | ACCUM | PERCT | CLASS | CFS | TOTAL | ACCUM | PERCT | CLASS | CFS | TOTAL | ACCUM | PERCT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00 | 0 | 13149 | 100.0 | 9 | 63000.00 | 669 | 11686 | 88.9 | 18 | 160000.0 | 808 | 5184 | 39.4 | 27 | 410000 | 188 | 665 | 5.0 |
| 1 | 27800.00 | 19 | 13149 | 100.0 | 10 | 70000.00 | 885 | 11017 | 83.8 | 19 | 180000.0 | 629 | 4376 | 33.3 | 28 | 450000 | 148 | 477 | 3.6 |
| 2 | 31000.00 | 18 | 13130 | 99.9 | 11 | 78000.00 | 671 | 10132 | 77.1 | 20 | 200000.0 | 656 | 3747 | 28.5 | 29 | 500000 | 127 | 329 | 2.5 |
| 3 | 34000.00 | 33 | 13112 | 99.7 | 12 | 86000.00 | 832 | 9461 | 72.0 | 21 | 220000.0 | 522 | 3091 | 23.5 | 30 | 550000 | 90 | 202 | 1.5 |
| 4 | 38000.00 | 62 | 13079 | 99.5 | 13 | 96000.00 | 932 | 8629 | 65.6 | 22 | 240000.0 | 565 | 2569 | 19.5 | 31 | 610000 | 64 | 112 | .8 |
| 5 | 42000.00 | 167 | 13017 | 99.0 | 14 | 110000.00 | 606 | 7697 | 58.5 | 23 | 270000.0 | 424 | 2004 | 15.2 | 32 | 680000 | 27 | 48 | .3 |
| 6 | 47000.00 | 296 | 12850 | 97.7 | 15 | 120000.00 | 517 | 7091 | 53.9 | 24 | 300000.0 | 333 | 1580 | 12.0 | 33 | 750000 | 18 | 21 | .1 |
| 7 | 52000.00 | 407 | 12554 | 95.5 | 16 | 130000.00 | 506 | 6574 | 50.0 | 25 | 330000.0 | 349 | 1247 | 9.5 | 34 | 830000 | 3 | 3 | .0 |
| 8 | 57000.00 | 461 | 12147 | 92.4 | 17 | 140000.00 | 884 | 6068 | 46.1 | 26 | 370000.0 | 233 | 898 | 6.8 | | | | | |

# APPENDIX 4

Compilation of miscellaneous quality of surface-water data collected in the St. Louis area, 1967-70

| Map number | Date of collection | Discharge (cfs) | Temperature (°C) | Milligrams per liter: Silica ($SiO_2$) | Iron (Fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Organic nitrogen (N) | Ammonia nitrogen (N) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Phosphorus ($PO_4$) | Detergents (MBAS) | Dissolved solids (residue at 180°C) | Hardness as $CaCO_3$: Calcium magnesium | Hardness as $CaCO_3$: Noncarbonate | Specific conductance (micromhos at 25°C) | pH | Color | Turbidity (JTU) | Chemical oxygen demand mg/l | Dissolved oxygen: Milligrams per liter | Dissolved oxygen: Percent saturation | Colonies per 100 milliliters: Total coliform | Fecal coliform | Fecal streptococci |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cuivre River near Old Monroe, Mo. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | 11-3-70 | ------ | 10.0 | 15 | 1.5a/ | .30a/ | 54 | 8.3 | 6.7 | 3.1 | ---- | --- | 208 | 29 | 8.2 | .0 | 4.6 | --- | --- | 239 | 170 | 27 | 380 | 7.6 | -- | -- | -- | 10.5 | 93 | 2100 | 1000 | 200 |
| Peruque Creek near O'Fallon, Mo. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | 7-15-70 | 24 | 23.5 | 12 | 3.9a/ | .56a/ | 50 | 8.0 | 11 | 2.7 | ---- | --- | 182 | 21 | 17 | .3 | 2.8 | --- | --- | 245 | 156 | 12 | 370 | 7.7 | -- | -- | -- | 5.0 | 58 | 7200 | 5800 | 2900 |
| 10 | 11-4-70 | 12 | 8.0 | 16 | 1.5a/ | .35a/ | 57 | 11 | 18 | 4.0 | ---- | --- | 206 | 34 | 28 | .2 | 5.4 | --- | --- | 293 | 189 | 31 | 480 | 7.5 | -- | -- | -- | 9.3 | 78 | 3300 | 1100 | 240 |
| Dardenne Creek near Weldon Spring, Mo. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | 7-15-70 | 3.6 | 24.5 | 12 | 2.8a/ | .62a/ | 60 | 9.0 | 8.3 | 2.1 | ---- | --- | 232 | 16 | 6.2 | .2 | .4 | --- | --- | 252 | 186 | 0 | 400 | 8.0 | -- | -- | -- | 5.1 | 61 | 5800 | 5000 | 1500 |
| 15 | 11-3-70 | 37 | 9.0 | 12 | 1.0a/ | .16a/ | 47 | 7.7 | 6.2 | 2.3 | ---- | --- | 170 | 24 | 5.7 | .0 | 5.2 | --- | --- | 205 | 150 | 16 | 340 | 7.6 | -- | -- | -- | 10.3 | 89 | 880 | 110 | 230 |
| Meramec River at Pacific, Mo. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 36 | 12-13-67 | ------ | 6 | 10 | .19 | .01 | 20 | 12 | 4.3 | 1.6 | .39 | .04 | 109 | 12 | 2.5 | .2 | .2 | .14 | .04 | 126 | 100 | 10 | 210 | 7.3 | 6 | 16 | 15 | 10.8 | 87 | ---- | ---- | ---- |
| Big River at Byrnesville, Mo. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 50 | 9-15-67 | 100 | 22 | 5.4 | .18 | .07 | 55 | 35 | 5.1 | 2.0 | ---- | --- | 292 | 46 | 7.7 | .2 | .2 | .02 | .0 | 296 | 281 | 42 | 521 | 8.1 | 5 | -- | -- | 8.5 | 96 | ---- | ---- | ---- |
| 50 | 12-13-67 | 4570 | 6 | 9.2 | .02 | .08 | 27 | 14 | 4.2 | 2.1 | 1.0 | .03 | 137 | 19 | 2.6 | .2 | .2 | .30 | .03 | 157 | 125 | 13 | 260 | 7.4 | 11 | 29 | 26 | 11.3 | 91 | ---- | ---- | ---- |
| Joachim Creek at Hematite, Mo. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 67 | 9-14-67 | 5.1 | ---- | 4.1 | .07 | .04 | 51 | 33 | 14 | 3.0 | ---- | --- | 292 | 36 | 17 | .1 | .2 | .18 | .0 | 300 | 263 | 24 | 531 | 8.1 | 7 | -- | -- | --- | -- | ---- | ---- | ---- |
| 67 | 12-14-67 | ------ | 5 | 8.3 | .30 | .02 | 24 | 15 | 4.7 | 2.0 | .56 | .07 | 122 | 24 | 3.0 | .1 | .5 | .05 | .04 | 158 | 122 | 20 | 254 | 7.4 | 21 | 19 | 14 | 11.7 | 91 | ---- | ---- | ---- |
| 67 | 7-16-70 | 4.9 | 26.5 | 9.8 | .40a/ | .07a/ | 56 | 30 | 10 | 2.1 | ---- | --- | 304 | 34 | 16 | .0 | .0 | --- | --- | 326 | 264 | 24 | 600 | 8.2 | -- | -- | --- | 7.4 | 91 | 3600 | <100 | 400 |
| 67 | 11-5-70 | 20 | 7.5 | 5.9 | .12a/ | .01a/ | 54 | 32 | 11 | 2.3 | ---- | ---. | 304 | 43 | 14 | .1 | .4 | --- | --- | 331 | 267 | 18 | 570 | 7.6 | -- | -- | -- | 8.9 | 74 | 140 | 20 | 64 |
| Little Creek near Mapaville, Mo. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 71 | 9-14-67 | 2.5 | ---- | 4.8 | .08 | .00 | 35 | 23 | 6.4 | 2.2 | ---- | --- | 200 | 22 | 8.9 | .2 | .2 | .03 | .0 | 201 | 182 | 18 | 366 | 7.9 | -- | -- | -- | --- | -- | ---- | ---- | ---- |
| Plattin Creek at Plattin, Mo. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 76 | 7-16-70 | 6.0 | 23.0 | 11 | .16a/ | .02a/ | 50 | 27 | 2.9 | 1.3 | ---- | --- | 276 | 26 | 3.7 | .2 | 1.1 | --- | --- | 291 | 236 | 12 | 450 | 8.2 | -- | -- | -- | 6.6 | 76 | 5400 | 100 | 1000 |
| 76 | 11-5-70 | 15 | 13.5 | 8.0 | .30a/ | .02a/ | 46 | 27 | 3.1 | 1.4 | ---- | --- | 272 | 34 | 3.2 | .1 | .8 | --- | --- | 275 | 228 | 8 | 460 | 8.1 | -- | -- | -- | 11.4 | 108 | 400 | 14 | 100 |
| Plattin Creek at Crystal City, Mo. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 79 | 9-14-67 | 4.9 | ---- | 9.1 | .12 | .04 | 52 | 31 | 3.3 | 1.6 | ---- | --- | 280 | 27 | 3.0 | .2 | .3 | .03 | .0 | 265 | 257 | 28 | 464 | 8.1 | 6 | -- | -- | --- | -- | ---- | ---- | ---- |
| 79 | 12-14-67 | ------ | 6 | 9.4 | .27 | .03 | 36 | 21 | 5.0 | 2.1 | .54 | .04 | 170 | 40 | 2.7 | .1 | .2 | .18 | .04 | 200 | 177 | 37 | 349 | 7.7 | 21 | 22 | 13 | 11.0 | 89 | ---- | ---- | ---- |
| 79 | 7-16-70 | ------ | 24.5 | 11 | .49a/ | .17a/ | 68 | 28 | 3.6 | 1.5 | ---- | --- | 278 | 31 | 4.2 | .2 | .0 | --- | --- | 300 | 284 | 56 | 440 | 8.2 | -- | -- | -- | 6.6 | 79 | 3200 | <100 | 80 |

a/ Total

# APPENDIX 5

Summary of annual average water-quality characteristics of the Missouri River at Howard Bend Plant near St. Louis, Missouri, 1951-70; analyses by City of St. Louis

| Annual average for year ending March 31 | Milligrams per liter | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Silica ($SiO_2$) | Iron oxide ($Fe_2O_3$) and aluminum oxide ($Al_2O_3$) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) and potassium (K) | Carbonate ($CO_3$) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Dissolved solids (residue at 105°C) | Alkalinity as $CaCO_3$ | Hardness as $CaCO_3$ | Color | Turbidity (JTU) | pH | Temperature (°C) | Total coliform (Col/100 ml) |
| 1951-------- | 13 | 0.5 | 52 | 14 | 41 | 0 | 172 | 107 | 19 | --- | 5.7 | 344 | 140 | 188 | 18 | 1,760 | 8.1 | 13 | 7,500 |
| 1952-------- | 12 | 0.3 | 52 | 14 | 30 | 0 | 168 | 81 | 17 | --- | 5.8 | 313 | 137 | 189 | 15 | 1,400 | 8.0 | 13 | 6,800 |
| 1953-------- | 14 | 0.4 | 59 | 18 | 47 | 0 | 198 | 125 | 21 | 0.4 | 5.2 | 402 | 165 | 223 | 12 | 1,100 | 8.2 | 14 | 5,500 |
| 1954-------- | 14 | 0.2 | 60 | 19 | 57 | 0 | 196 | 162 | 23 | 0.5 | 4.6 | 403 | 162 | 230 | 11 | 760 | 8.1 | 15 | 5,300 |
| 1955-------- | 11 | 0.8 | 53 | 16 | 51 | 0 | 169 | 118 | 21 | 0.5 | 5.8 | 370 | 138 | 196 | 15 | 890 | 8.0 | 15.5 | 5,200 |
| 1956-------- | 11 | 1.5 | 56 | 17 | 58 | 0 | 182 | 139 | 26 | 0.5 | 4.5 | 410 | 149 | 211 | 13 | 500 | 8.0 | 15 | 4,000 |
| 1957-------- | 11 | 0.9 | 54 | 18 | 55 | 0 | 178 | 136 | 26 | 0.5 | 4.4 | 404 | 146 | 207 | 14 | 500 | 8.2 | 15.5 | 4,000 |
| 1958-------- | 10 | 0.9 | 50 | 15 | 43 | 0 | 160 | 107 | 24 | 0.4 | 5.2 | 339 | 132 | 185 | 17 | 700 | 8.0 | 15 | 9,800 |
| 1959-------- | 12 | 3.5 | 53 | 14 | 42 | 0 | 176 | 98 | 24 | 0.4 | 4.6 | 338 | 144 | 192 | 20 | 700 | 8.0 | 15 | 5,100 |
| 1960-------- | 12 | 1.3 | 55 | 16 | 44 | 0 | 183 | 103 | 23 | 0.5 | 4.4 | 351 | 151 | 204 | 19 | 900 | 8.1 | 15 | 5,400 |
| 1961-------- | 12 | 1.2 | 57 | 16 | 46 | 0 | 187 | 107 | 22 | 0.4 | 4.9 | 367 | 153 | 208 | 18 | 850 | 8.1 | 14.5 | 19,000 |
| 1962-------- | 11 | 1.2 | 51 | 13 | 34 | 0 | 170 | 80 | 17 | 0.3 | 4.5 | 302 | 139 | 183 | 21 | 700 | 8.1 | 14 | 8,500 |
| 1963-------- | 13 | 1.1 | 64 | 18 | 49 | 0 | 206 | 119 | 23 | 0.5 | 5.4 | 425 | 169 | 233 | 19 | 700 | 8.2 | 15 | 8,700 |
| 1964-------- | 12 | 0.8 | 64 | 19 | 63 | 0 | 199 | 157 | 29 | 0.5 | 4.6 | 479 | 163 | 238 | 15 | 475 | 8.1 | 15 | 6,800 |
| 1965-------- | 10 | 0.9 | 55 | 15 | 54 | 0 | 170 | 130 | 24 | 0.5 | 4.8 | 391 | 140 | 200 | 16 | 860 | 8.0 | 15 | 13,000 |
| 1966-------- | 10 | 1.4 | 58 | 14 | 42 | 0 | 185 | 112 | 23 | 0.4 | 4.2 | 362 | 153 | 204 | 16 | 700 | 8.1 | 14.5 | 21,000 |
| 1967-------- | 11 | 1.8 | 59 | 18 | 59 | 0 | 198 | 143 | 26 | 0.4 | 3.6 | 436 | 165 | 220 | 16 | 309 | 8.0 | 14 | 5,100 |
| 1968-------- | 9.2 | 1.2 | 55 | 15 | 49 | 0 | 180 | 120 | 21 | 0.4 | 3.3 | 384 | 148 | 201 | 18 | 364 | 8.0 | 14 | 9,900 |
| 1969-------- | 11 | 1.0 | 55 | 14 | 46 | 0 | 163 | 120 | 21 | 0.4 | 5.7 | 378 | 138 | 194 | 17 | 383 | 8.1 | 14 | 12,000 |
| 1970-------- | 10 | 0.8 | 57 | 16 | 43 | 0 | 190 | 109 | 20 | 0.4 | 4.5 | 383 | 156 | 208 | 13 | 396 | 8.0 | 13.5 | 19,000 |

# APPENDIX 6

Summary of annual average water-quality characteristics of the Mississippi River at Chain of Rocks Plant at St. Louis, Missouri, 1951-70; analyses by City of St. Louis

| Annual average for year ending March 31 | Silica ($SiO_2$) | Milligrams per liter | | | | | | | | | | | | | | Color | Turbidity (JTU) | pH | Temperature (°C) | Total coliform (Col/100 ml) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Iron oxide ($Fe_2O_3$) and aluminum oxide ($Al_2O_3$) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) and potassium (K) | Carbonate ($CO_3$) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Dissolved solids (residue at 105°C) | Alkalinity as $CaCO_3$ | Hardness as $CaCO_3$ | | | | | | |
| 1951-------- | 13 | 0.4 | 50 | 14 | 38 | 1 | 162 | 101 | 18 | ---- | 5.8 | 325 | 135 | 186 | | 17 | 1,400 | 7.8 | 13.5 | 7,300 |
| 1952-------- | 14 | 0.3 | 51 | 15 | 32 | 1 | 166 | 82 | 18 | ---- | 5.5 | 311 | 138 | 189 | | 18 | 1,200 | 7.8 | 14.5 | 19,000 |
| 1953-------- | 15 | 0.2 | 57 | 18 | 46 | 1 | 190 | 122 | 21 | 0.3 | 5.3 | 381 | 158 | 217 | | 14 | 960 | 8.0 | 15.5 | 7,700 |
| 1954-------- | 14 | 0.2 | 58 | 19 | 56 | 1 | 187 | 153 | 23 | 0.4 | 4.5 | 423 | 155 | 225 | | 15 | 700 | 8.0 | 15.5 | 5,600 |
| 1955-------- | 12 | 0.3 | 53 | 16 | 45 | 1 | 164 | 114 | 23 | 0.4 | 6.1 | 364 | 136 | 195 | | 17 | 850 | 8.0 | 15.5 | 7,700 |
| 1956-------- | 11 | 0.3 | 55 | 17 | 51 | 1 | 176 | 130 | 26 | 0.3 | 5.8 | 409 | 146 | 207 | | 15 | 400 | 8.0 | 15 | 4,900 |
| 1957-------- | 10 | 0.4 | 53 | 17 | 50 | 1 | 171 | 131 | 25 | 0.4 | 4.5 | 393 | 142 | 203 | | 16 | 400 | 7.9 | 15.5 | 5,600 |
| 1958-------- | 11 | 0.3 | 51 | 14 | 37 | 1 | 156 | 102 | 23 | 0.3 | 4.7 | 341 | 131 | 185 | | 19 | 630 | 7.9 | 14.5 | 10,000 |
| 1959-------- | 11 | 0.3 | 52 | 14 | 35 | 1 | 167 | 90 | 23 | 0.3 | 4.3 | 331 | 139 | 188 | | 19 | 565 | 8.0 | 15 | 10,000 |
| 1960-------- | 12 | 0.3 | 56 | 15 | 37 | 1 | 181 | 95 | 24 | 0.3 | 4.9 | 348 | 150 | 202 | | 19 | 775 | 8.0 | 14.5 | 8,900 |
| 1961-------- | 11 | 0.3 | 57 | 15 | 40 | 1 | 185 | 98 | 27 | 0.3 | 6.4 | 356 | 154 | 206 | | 17 | 700 | 8.1 | 14.5 | 9,300 |
| 1962-------- | 11 | 0.3 | 52 | 13 | 30 | 1 | 168 | 75 | 21 | 0.3 | 5.9 | 300 | 139 | 185 | | 20 | 662 | 8.1 | 14 | 16,000 |
| 1963-------- | 13 | 0.4 | 63 | 18 | 30 | 1 | 202 | 87 | 27 | 0.3 | 5.8 | 399 | 168 | 230 | | 17 | 568 | 8.2 | 14 | 13,000 |
| 1964-------- | 12 | 0.2 | 62 | 19 | 39 | 1 | 197 | 104 | 31 | 0.4 | 5.5 | 450 | 163 | 233 | | 13 | 342 | 8.2 | 15 | 7,200 |
| 1965-------- | 11 | 0.4 | 54 | 15 | 49 | 1 | 169 | 127 | 22 | 0.3 | 5.0 | 379 | 140 | 197 | | 16 | 711 | 8.2 | 14 | 31,000 |
| 1966-------- | 11 | 0.4 | 54 | 16 | 40 | 1 | 174 | 109 | 19 | 0.3 | 5.0 | 354 | 144 | 198 | | 16 | 626 | 8.2 | 15 | 31,000 |
| 1967-------- | 9.8 | 0.6 | 58 | 18 | 53 | 1 | 186 | 141 | 23 | 0.4 | 4.4 | 409 | 159 | 219 | | 13 | 258 | 8.0 | 14.5 | 10,000 |
| 1968-------- | 10 | 0.5 | 54 | 16 | 48 | 0 | 176 | 118 | 21 | 0.3 | 6.2 | 381 | 144 | 198 | | 13 | 352 | 8.1 | 14.5 | 7,900 |
| 1969-------- | 11 | 0.2 | 54 | 14 | 47 | 0 | 170 | 121 | 20 | 0.2 | 5.3 | 370 | 130 | 194 | | 13 | 348 | 8.2 | 14 | 48,000 |
| 1970-------- | 13 | 0.2 | 57 | 15 | 39 | 0 | 180 | 106 | 21 | 0.2 | 3.6 | 372 | 148 | 206 | | 14 | 442 | 8.1 | 14.5 | 25,000 |

# APPENDIX 7

## DEFINITION OF TERMS AND CONVERSION OF UNITS

**Acre-foot** — The volume of water required to cover one acre to a depth of 1 foot.

1 acre-foot = 43,560 cubic feet
= 325,851 gallons

**Alluvium** — A general term for all detrital deposits resulting from the operations of modern rivers, thus including the sediments laid down in riverbeds, floodplains and lakes.

**Anticline** — A fold or arch of rock strata, dipping in opposite directions from an axis.

**Aquifer** — A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

**Artesian water** — Ground water under sufficient pressure to rise above the level at which the water-bearing bed is reached in a well. Ground water under artesian pressure is also called confined water.

**Confining bed** — A body of relatively impermeable material stratigraphically adjacent to one or more aquifers.

**Connate water** — Water entrapped in interstices of a sedimentary rock at the time the rock was deposited.

**Continuous-record station** — A site on a stream where continuous records of discharge are obtained.

**Cubic feet per second (cfs)** — The unit expressing rate of discharge. One cfs is the rate of discharge of a stream having a cross-sectional area of 1 square foot and an average velocity of 1 foot per second.

1 cfs = 7.48 U.S. Gallons per second
= 449 U.S. Gallons per minute
= 0.646 millions of U.S. gallons per day.

**Disconformity** — An unconformity in which the beds on opposite sides are parallel.

**Dolomite** — A term applied to rocks that approximate the mineral dolomite [$CaMg(CO_3)_2$] in composition.

**Epicontinental sea** — Those shallow portions of the sea which lie upon the continental shelf, and those portions which extend into the interior of the continent with like shallow depths, such as the Baltic Sea and Hudson Bay.

**Evapotranspiration** — The movement of water into the atmosphere by the combined processes of direct evaporation and transpiration by plants.

**Fault** — A fracture or fracture zone in the rocks along which there has been displacement of the two sides relative to one another, parallel to the fracture.

**Groundwater reservoir** — See aquifer.

**Hydrology** — The science that relates to the water of the earth.

**Intermittent stream** — A stream that flows only part of the time or through only part of its reach.

**Lithology** — The physical character of a rock.

**Loess** — A sediment, commonly nonstratified and unconsolidated, composed dominantly of silt-size particles, with accessory clay and sand, deposited primarily by the wind.

**Low flow** — The portion of stream discharge that is derived primarily from groundwater outflow.

**Partial-record station** — A site on a stream where occasional discharge measurements have been collected over a period of years.

**Perennial stream** — A stream that flows continuously throughout its reach.

**Permeability** — A measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient.

**Porosity** — The property of a rock or soil containing voids.

**Potentiometric surface** — A surface which represents the static head. As related to an aquifer it is definea by the levels to which water will rise in tightly cased wells.

**Recharge** — The addition of water to the zone of saturation. Infiltration of precipitation is a form of natural recharge.

**Recurrence interval** — The average interval of time within which a given event will be exceeded once. Recurrence intervals are averages and do not imply regularity of occurrence; an event of 50-year recurrence interval might be exceeded in consecutive years or it might not be exceeded in a 100-year period. In other words, a 50-year drought or flood has a 2-percent chance of occurrence in any year.

**Regional dip** — The general inclination of strata over a large area in which they dip in one direction with or without interruptions.

**Residual errors** — Ratio of observed values of streamflow characteristics at gaging stations to the values computed from equations.

**Seepage run** — A series of discharge measurements made in a short time to identify stream reaches where gains or losses in flow occur.

**7-day $Q_2$** — The annual minimum average discharge for seven consecutive days that will occur on an average of once in 2 years. This is an index to the low-flow potential of a stream and can be used as a guide in comparing one stream to another.

**Soil infiltration index** — This value is the maximum potential difference, in inches, between storm rainfall and storm runoff. It is dependent on soil-water storage and infiltration rates of a watershed.

**Specific capacity** — The rate of discharge of water from a well divided by the drawdown of water level in the well. If a well yields 500 gpm with a drawdown of 25 feet, its specific capacity is 500/25 or 20 gpm per foot of drawdown.

**Specific conductance** — A measure of the capacity of water to conduct a current of electricity, expressed in micromhos per centimeter at 25°C. Conductance varies with the quantities of dissolved mineral constituents and with the degree of ionization of the constituents as well as with the temperature of the water. It is useful in indicating the approximate concentration of mineral matter in water.

**Standard error of estimate** — A measure of the reliability of a regression. It is the standard deviation of the distribution of residuals about the regression line.

**Storage coefficient** — The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

**Transmissivity** — The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

**Transpiration** — The process by which water vapor escapes from a living plant and enters the atmosphere.

**Tributary streams** — Those streams that originate in or have much of their drainage basin in the project area.

**Unconformity** — A surface of erosion or nondeposition that separates younger strata from older rocks.

**Water table** — That surface in an unconfined water body at which the pressure is atmospheric.

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